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Beaufort Environmental Monitoring Project 1984-1985 Final Report

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Beaufort Environmental Monitoring Project 1984-1985 Final Report

Northern Affairs Program

ESL Environmental Sciences Limited
LGL Limited
ESSA Limited
Arctic Laboratories Limited
Arctic Sciences Limited

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FOREWORD

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PREFACE

The restricted objectives of the Beaufort Environmental Monitoring Project should be emphasized. The intent of the project is *not* to provide recommendations for a definitive research program which would address all the fundamental knowledge gaps that exist in the Beaufort region. The cost of acquiring these data would be very high and may still fail to address the issues which finally emerge as those of regulatory and public concern. The objective of BEMP is to identify and recommend those research and monitoring activities which are considered necessary for the responsible management of a phased development of Beaufort Sea hydrocarbons, through the administration of the relevant legislation administered by INAC. The specific focus and objectives of BEMP should not detract from an overall recognition of our fundamental knowledge gaps in the Beaufort. Encouragement and support should be given to those agencies with responsibilities to conduct research programs which reflect their particular mandate in this region.

David P. Stone
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RÉSUMÉ

Le projet de surveillance environnementale de la mer de Beaufort (PSEB) a été entrepris en 1983 par le ministère des Affaires indiennes et du Nord canadien et par le ministère de l'Environnement. Ce projet doit permettre d'obtenir les données techniques de base nécessaires pour concevoir, exécuter et évaluer un programme de recherche et de surveillance environnementales qui soit à la fois complet et justifiable. Ce programme sera mis en oeuvre parallèlement à l'exploitation graduelle des hydrocarbures dans le mer de Beaufort. Le présent rapport fait état des activités qui doivent se dérouler pendant la deuxième année pendant laquelle portera le projet et renferme des recommandations quant aux études environnementales qui pourraient être entreprises à l'avenir.

Les principales activités exécutées en 1984-1985 ont consisté à examiner, avant la tenue de l'atelier, les études entreprises depuis décembre 1983, à présenter, dans des descriptions de projets, le but poursuivi par ces recherches ainsi que les rapports qu'elles présentent avec les hypothèses actuellement formulées dans le cardre du PSEB, à offrir un atelier au début de février 1985 et à rédiger le présent rapport. Au cours de l'atelier proprement dit, on a examiné les études récentes et en cours à la lumière de chaque hypothèse formulée, on a incorporé les nouvelles données ainsi obtenues dans les hypothèses déjà avancées et on a formulé des recommandations concernant l'exécution de travaux de recherche et de surveillance plus approfondis. Comme l'utilisation éventuelle de fluides de forage à base d'huile a changé le scénario de l'exploitation des hydrocarbures, les répercussions que pourrait avoir sur les poissons anadromes le déversement de débris contaminés par le pétrole a également donné lieu à la formulation et à l'évaluation d'une nouvelle hypothèse au cours de l'atelier de 1985.

On trouvera ci-après un résumé des conclusions et des recommandations émises à l'issue des discussions qu ont été engagées relativement à chaque hypothèse. Le corps du rapport renferme un aperçu des nouvelles données lesquelles présentent un rapport avec les diverses ramications que pourraient avoir les hypothèses émises dans le cadre du PSEB; on y trouve également les facteurs qui justifient les recommandations qui ont été formulées en matière de recherche et de surveillance. En annexe figurent de brèves descriptions des travaux de recherche effectués récemment ou en cours d'exécution lesquels ont été jugés pertinents au projet.

HYPOTHESE N° 1: Le trafic maritime, l'exploration sismique et la présence d'installations en activité au large des côtes entraineront une diminution de la population de baleines boréales dans l'ouest de l'océan Arctique.

De nombreuses études relatives à l'hypothèse n° 1 ont été effectuées depuis le tenue du dernier atelier dans le cadre du PSEB. L'examen de ces études a permis de conclure que cette hypothèse et les ramifications qui lui sont attribuées restent valides. Au cours de l'atelier qui s'est tenu en février 1985, on a d'ailleurs ajouté à cette hypothèse une nouvelle ramification, à savoir que les effets produits par toutes les activités industrielles se déroulant au large des côtes se combineront pour exclure les baleines boréales d'une vaste zone, soit toute le zone industrielle. Cette nouvelle ramification a été formulée pour souligner l'importance accrue que prennent les travaux de recherche portant sur les répercussions cumulatives de l'exploitation des hydrocarbures sur les baleines boréales et, en même temps, pour témoigner de l'importance secondaire qui est accordée à l'évaluation des répercussions à court terme, particulières à des sites bien déterminés. On sait également, grâce aux informations recueillies au cours de l'année dernière, qu'une combinaison de facteurs biologiques et physiques peut conditionner ou influencer les écarts que présente annuellement la répartition des baleines boréales qui fréquentent en été la partie sud-est de la mer de Beaufort. Les facteurs qui offrent à cet égard un intérêt particulier sont ceux qui sont à l'origine des écarts considérables observés dans l'abondance et le répartition du zooplancton dont les baleines boréales font leur principale nourriture.

Le groupe a recommandé qu'en 1985 les travaux de recherche et de surveillance consistent prioritairement à: 1) poursuivre les études et les enquêtes méthodiques portant sur le comportement à

long terme des baleines (au moyen de photographies aériennes de baleines individuelles) 2) effectuer des études sur la répartiion et l'extistence des denrées (par rapport aux phénomènes océanographiques et à la répartition des baleines boréales). Ces programmes de recherche permettront d'obtenir les renseignements nécessaire pour déterminer si une portion quelconque de la population de baleines boréales ne fréquente par la zone industrielle située au large des côtes. Ils permettront également de mettre à jour des données plus complètes sur les facteurs naturels qui peuvent avoir en partie causé les écarts observés dans la répartition des baleines boréales depuis que des enquêtes méthodiques ont été entreprises en 1980. Les membres du sous-groupe se sont unanimement entendus pour engager les travaux de recherche dans ces deux voies, mais certains éléments de la stratégie ou de la conception des projets individuels ont suscité des divergences d'opinion.

HYPOTHESE N° 2: Les diverses activités et installations liées à l'exploitation des hydrocarbures au large des côtes réduiront les prises de bélugas.

Les participants confirment la validité de cette hypothèse, mais concluent qu'il y aurait lieu d'attacher moins d'importance à plusieurs de ses ramications. En particulier, le groupe a conclu que compte tenu de l'actuel scénario d'exploitation des hydrocarbures, il était peu probable que la présence d'îles artificielles au large des côtes retarde la débâcle et que la circulation de brise-glaces cause une débâcle prématurée. De même, il a été conclu que le trafic maritime actuel n'était pas assez intense pour empêcher les bélugas de pénétrer dans l'estuaire du Mackenzie, mais qu'il pouvait modifier la répartition des bélugas localement et à court terme. Le fait que les chasseurs trouveront un emploi rémunéré auprès de sociétés pétrolières changera peut-être la façon dont la chasse est pratiquée, mais les participants ne s'attendent pas à ce que les prises de bélugas s'en trouvent considérablement changées.

Les participants ont discuté des travaux de recherche destinés à déterminer les facteurs naturels qui influent sur la répartition des bélugas dans l'estuaire du Mackenzie, mais ils ont finalement conclu que de tels travaux n'étaient pas nécessaires à l'heure actuelle. Cette conclusion se justifie par le fait qu'il existe déjà, sur la répartition habituelle des bélugas, une base de données adéquate qui nous permettrait de déceler tout écart notable attribuable à des activités industrielles. En outre, les sociétés d'exploitation se sont déjà engagées à calmer l'inquiétude qu'ont soulevée les répercussions possibles de leurs activités sur les prises de bélugas. Les participants n'ont pas jugé nécessaire d'augmenter l'actuel programme de surveillance des bélugas; il pourrait être possible d'en réduire la fréquence à une fois toius les deux ou trois ans.

Les participants ont également recommandé de continuer à surveiller les débâcles, l'importance des prises et les répercussions que peuvent avoir les activités industrielles sur les prises de bélugas.

HYPOTHESE N° 3: Le tafic maritime, les activités sismiques, le dragage, le trafic aérien et la présence de plates-formes de forage /d'îles artificielles exploitées au large des côtes réduiront la population de phoques barbus et annelés dans la mer de Beaufort.

Les participants ont dit s'attendre à ce que cette hypothèse et ses ramifications restent valides, mais ils ont conclu que les effets cumulatifs de toutes les ramifications seraient probablement négligeables ou trop difficiles à déceler (en raison de la variabilité naturelle des populations) étant donné l'échelle sur laquelle sont actuellement exploités les hydrocarbures dans la mer de Beaufort. Par exemple, des études effectuées chaque année, depuis 1981, par le ministère des Pêches et océans (Institut des eaux douces) n'ont révélé aucune corrélation entre le nombre peu élevé de phoques capturés et la mise en oeuvre, à proximité, d'activités industrielles. Les participants s'attendaient à ce que les cas d'abandon de l'habitat par suite de la présence d'installations au large des côtes et du trafic maritime soient minimes tant pour ce qui est des individus que pour ce qui est des populations. Ils s'attendaient également à ce que la quantité d'énegie dépensée par les phoques pour éviter les zones survolées par des aéronefs ou pour plonger en réaction contre le trafic aérien sont négligeable, à l'échelle régionale.

Les participants n'ont recommandé aucun programme de recherche ou de surveillance particulier pour donner suite à cette hypothèse.

HYPOTHESE N° 4: La frequence accrue de passage de brise-glaces dans la banquises côtière et dans le golfe Amundsen réduira le taux de reproduction des phoques annelés et aura des répercussions ultérieures sur les densités de population.

Après avoir examiné cette hypothèse et ses ramifications, les participants ont conclu qu'elle restait valide telle qu'elle avait été formulée dans la rapport PSEB présenté en 1983-1984. Une quatrième ramification a toutefois été ajoutée por tenir compte du fait qu'une baisse du taux de reproduction des phoques annelés entraînera une diminution des densités de population; l'hypothèse a donc été reformulée en conséquence. Il a été conclu que les secteurs de l'habitat qui pourraient être perdus par suite de la présence de brise-glaces seraient minimes comparativement à l'étendue de l'habitat dont les phoques annelés disposeraient encore dans la région pour s'accoupler. Le nombre de jeunes phoques annelés dont le passage de brise-glaces entraînerait la perte directe représenterait, selon les participants, une portion infime de la totalité des jeunes phoques.

Pendant qu'ils étudiaient cette hypothèse à la lumière de chacune de ses ramifications, les participants ont discuté des travaux de recherche qui permettraient d'accroître considérablement notre compréhension des facteurs qui influent sur la reproduction des phoques annelés dans le golfe Amundsen ainsi que des éventuelles répercussions qu'aurait la rupture de la banquise provoquée par les brise-glaces sur les aires de mise bas. Les participants se sont toutefois généralement entendus pour dire que ces travaux de recherche ne seraient pas possibles avant que des brise-glaces ne commencent à sillonner le golfe. Le groupe a par ailleurs recommandé de continuer à recueillir les images prises par satellite pour qu'elles puissent ultérieurement servir d'une part à étudier dans quelle mesure la reproduction et la survie des phoques annelés sont liées à la condition de la glace, et, d'autre part, à régler le problème posé par la rupture de la banquise provoquée par le passage de brise-glaces.

HYPOTHESE N° 5: Le passage de brise-glaces dans la zone de transition (cisaillement) entrainera une baisse de taux de reproduction des phoques barbus.

Aucun travail de recherche n'a été effectué relativement à cette hypothèse, mais les participants ont néanmoins conclu à sa validité. Peu de nouvelles données ont été recueillies sur les sons émis par les phoques barbus, sur leur comportement en période d'accouplement ainsi que sur l'incidence possible du passage de brise-glaces sur ces comportements (c.-à-d. diminution des sons émis par suite des perturbations et amortissement des cris en raison des bruits sous-marins). Le groupe a conclu qu'un programme de recherche pourrait être mis sur pied pour déterminer les répercussions directes du passage de brise-glaces sur les sons émis par les phoques. Toutefois, comme de telles recherches ne montreraient vraisemblablement pas comment une diminution de ces sons peut influer sur le succès des accouplements et sur les comportements adoptés en période d'accouplement, il a été décidé d'attacher une importance secondaire à ces travaux, aux fins de la présente hypothèse.

Le passage de brise-glaces dans la zone de transition entraînera la mort de certains jeunes phoques barbus, mais le groupe s'attend à ce que ces pertes soient infimes étant donné le scénario actuellement adopté en matière d'exploitation des hydrocarbures. Comme il serait ardu de déceler les changements que la production de phoques pourrait subir par suite des pertes minimes prévues, aucun travail de recherche ou de surveillance n'a été recommandé relativement à cet aspect de l'hypothèse n° 5.

HYPOTHESE N° 6: La présence de brise-glaces dans le golfe Amundsen influera sur les populations de phoques annelés et d'ours blancs.

Comme cette hypothèse englobe tous les niveaux trophiques de l'écosystème marin du golfe Amundsen et qu'elle concerne des processus et des ressources biologiques caractérisés par un degré élevé de variabilité naturelle, la complexité et la testabilité de cette hypothèse ont donné lieu à des discussions poussées. On s'est néanmoins attendu à ce qu'elle demeure valide. Le ministère des Pêches et océans entreprend actuellement plusieurs projets de recherche qui fourniront des données relatives à l'une ou à plusieurs des ramifications associées à cette hypothèse. Des études portant sur les phoques

annelés (Station de biologie arctique) et sur les ours blancs (Service canadien de la faune) devraient produire des données qui seront utiles pour évaluer les principales conséquences de cette hypothèse. Bon nombre des incertitudes liées à l'hypothèse n° 6 concernent les renseignements limités dont on dispose sur la morue arctique et sur les rapports d'ordre trophique qu'elle entretient dans la région.

Outre la poursuite des programmes de recherche portant sur cette hypothèse, les participants à l'atelier n'ont recommandé la mise en oeuvre d'aucun autre programme de recherche ou de surveillance axé explicitement sur l'une ou l'autre des ramifications attribuées à cette hypothèse. Le sous-groupe a toutefois soulevé deux problèmes généraux au sujet de la disponibilité de données de base sur la couverture de glace dans la mer de Beaufort et dans le golfe Amundsen. Premièrement, l'actuel manque de communication entre les biologistes et les glaciologues nuirait, d'après les membres du sous-groupe, aux programmes de recherche existants. Il a donc été recommandé d'amener les représentants de chacune de ces disciplines à communiquer davantage entre eux. La deuxième préoccupation signalée venait de ce qu'aucun effort n'était actuellement déployé pour s'assurer qu'il existait, pour les glaces, des données obtenues à peu de frais, comme par exemple au moyen des images à haute résolution du satellite NOAA. Le groupe a donc conclu qu'il faudrait s'efforcer de poursuivre le cueillette et l'analyse des données relatives à la glace de mer dans le mesure où l'on vourdrait pour assurer l'interprétation optimale des résultats obtenus à la suite d'études biologiques. Les images disponibles devraient figurer dans des catalogues sommaires destinés à être ultérieurement consultés par des chercheurs de la région de la mer de Beaufort.

HYPOTHESE N° 7: La présence d'installations en activité entrainera une augmentation de la mortalité des ours blancs.

Après avoir examiné cette hypothèse et les ramifications qui lui sont attribuées, le groupe de travail a conclu qu'elles restaient toutes valides. Les employés préposés ux appareils de sondage continuent de signaler la présence d'ours à proximité des installations mises en place au large des côtes. Bien qu'un seul ours ait été détruit au cours de l'année dernière dans la région de la mer de Beaufort, des progrès considérables ont été accomplis pour ce qui est de la mise au point de méthodes visant à déceler et à éloigner les ours. Les recherches qui ont été effectuées récemment sur les moyens de déceler les ours ont porté sur le matériel micro-ondes et infrarouge. Les études portant sur les moyens d'éloigner les ours blancs ont quant à elles consisté à évaluer d'une manière plus approfondie l'efficacité des dispositifs sonores ainsi que des balles de caoutchouc et de plastique tirées au moyen d'un fusil.

Les participants à l'atelier de 1985 ont de nouveau apporté leur appui aux recherches axées sur les techniques visant à déceler et à éloigner les ours blancs ainsi que sur la possibilité d'utiliser certains instruments de détection pour recenser les mammifères marins. Le groupe a envisagé la possibilité qu'une étude soit effectuée pour déterminer si le fait que les ours blancs sont attirés par les installations ou qu'ils les évitene,t peut varier selon le sexe ou l'âge. Les participants se sont toutefois dits grandement inquietes de ne pas connaître le nombre d'ourses et d'oursons blancs qui étaient chassés en Alaska à des fins de subsistance. Comme on ne dispose pas de données appropriées à cet égard, il a été souligné que la diminution du nombre d'ours blancs dans la région de la mer de Beaufort pourrait être attribuée, à tort, soit à la chasse pratiquée par les Canadiens soit aux répercussions des activités industrielles.

HYPOTHESE N° 8: L'exploitation des hydrocarbures au large des côtes se traduira par une baisse de la prise d'ours blancs.

Les personnes qui ont participé à l'atelier précédent ont conclu que cette hypothèse était improbable et ont par conséquent conclu qu'elle ne justifiait pas la mise en oeuvre de quelque programme de contrôle ou de recherche que ce soit. Le groupe actuel est d'accord avec cette conclusion et cette recommandation globales compte tenu de l'échelle sur laquelle sont actuellement exploités les hydrocarbures dans la mer de Beaufort. Pendant la période de chasse à l'ours blanc, le sillage laissé par les

brise-glaces regèlerait rapidement et n'empêcherait probablement pas les chasseurs de se déplacer sur la banquise côtière.

Cependent, comme pour l'hypothèse précédente, le groupe a conclu que tout effort accompli ultérieurement pour exercer un contrôle quelconque se heurterait à l'absence de données sur la chasse à l'ours blanc pratiquée, en Alaska, à des fins de subsistance. Les participants ont indiqué que faute de renseignements appropriés sur cette question, il serait impossible de déterminer les causes de toute baisse ultérieure du nombre total d'ours blancs.

HYPOTHESE N° 9: Les déversements chroniques/épisodiques de pétrole causés par l'exploitation des hydrocarbures, dans le milieu marin et à proximité, entrainera la mortalité localisée d'ours blancs.

Des représentants de l'industrie pétrolière qui faisaient partie du sous-groupe ont réétudié cette hypothèse et ont indiqué que les déversements chroniques de pétrole provoqués par des activités d'exploration étaient à la fois rares et relativement peu importants. Des expériences faites auprès d'ours blancs en captivité ont néanmoins démontré qu'ils réagissaient très vivement au contact ou à l'ingestion de substances pétrolières. C'est pourquoi le groupe approuve et encourage la publication et la mise en oeuvre d'un plan d'action visant à protéger les ours blancs en cas de déversements graves; des biologistes, chargés par les autorités fédérales, territoriales et provinciales de s'occuper des ours blancs, ont élaboré ce plan d'action.

Les participants ont également recommandé de prévoir un plan qui permettrait de profiter des déversements accidentels pour en surveiller les répercussions. Dans un plan de ce genre, il faudrait 1) désigner une équipe de scientifiques chargés de prendre les mesures qui s'imposent en cas de déversement, 2) décrire la forme de surveillance qu'il y aurait lieu d'appliquer, dans l'éventualité d'un déversement, et comment l'exercer (y compris les travaux de recherche connexes). Bien qu'il ait été admis que le plan d'action destiné à protéger les ours blancs en cas de déversement devrait être bientôt diffusé, le groupe a conclu qu'il faudra peut-être modifier ultérieurement ce plan ou d'autres plans pour pouvoir exercer une surveillance, effectuer des recherches au gré des déversements ainsi que pour pouvoir tenir compte d'autres espèces de mammifères marins. Il importe également que des représentants de l'industrie pétrolière examinent le plus tôt possible le plan d'action en place pour que tous ses éléments soient bien intégrés aux plans actuels d'urgence qui sont prévus en cas déversement de pétrole dans le région de la mer de Beaufort.

Les participants ont étudié la possibilité que soit mis sur pied un programme de recherche destiné à découvrir comment les ours blancs se comportent devant des eaux recouvertes de pétrole ou des proies contaminées par le pétrole. Les participants ont toutefois conclu que l'idée de mettre sur pied un tel programme susciterait une forte opposition et ont, par conséquent, décidé de l'abandonner pour le moment.

HYPOTHESE N° 10: Les déversements chroniques/épisodiques de pétrole causés par l'exploitation des hydrocarbures, dans le milieu marin ou à proximité, entrainera la mortalité localisée de certaines espèces d'oiseaux.

Au cours de l'atelier de 1985, les participatns ont combiné cette hypothèse avec l'hypothèse n° 11 car ils ont constaté que cette dernière constituait tout simplement un cas particulier d'une hypothèse plus générale liée aux répercussions des déversements de pétrole chroniques sur les populations d'oiseaux. Pendant qu'ils combinaient ces deux hypothèses, les participants ont jugé non valides ou improbables plusieurs des ramifications qui avaient été originalement attribuées à l'hypothèse n° 11 et les ont, par conséquent, supprimées.

Le gros des discussions engagées au cours de l'atelier ont porté sur la nécessité de contrôler et de consigner les cas où des oiseaux (ou d'autres animaux) étaient contaminés par le pétrole, ceci afin de constituer un dossier sur les conséquences des déversement de pétrole accidentels. Les participants ne

se sont pas tous entendus sur cette question, en grande partie parce que le mortalité d'oiseaux attribuable à des déversements chroniques n'avait pas encore fait l'objet de rapports et parce que ce problème ne soulève pas beaucoup d'inquiétude dans les autres pays producteurs de pétrole.

Il a été conclu qu'il faudrait continuer de consigner dans les rapports sur les déversements de pétrole toute observation concernant les animaux contaminés par le pétrole. Comme la production d'hydrocarbures pourrait peut-être augmenter dans l'avenir, les déversements de pétrole chroniques pourraient être plus fréquents et plus étendus, ce qui pourrait alors justifier le mise en oeuvre d'un programme de surveillance méthodique. D'après les renseignements fournis par les représentants de l'industrie pétrolière pendant et après l'atelier, il y aurait eu un total de 38 déversements pendant la saison de forage 1984-1985, impliquant dans la plupart des cas, de quantités de pétrole relativement petites.

HYPOTHESE N° 11: La présence de nappes d'huile en eaux libres autour des plates-formes pendant la saison des glaces entrainera une augmentation de la mortalité des eiders et des canards plongeurs.

Cette hypothèse a été combinée avec l'hypothèse n°10 au cours de l'atelier et n'existe plus sous sa forme originale.

HYPOTHESE N° 12: Le passage fréquent d'avions à basse altitude au-dessus des bernaches accroîtera leur mortalité pendant l'hiver.

Comme on avait conclu à la non-validité de cette hypothèse au cours de l'atelier précédent, on ne l'a pas réexaminée cette année.

HYPOTHESE N° 13: Les installations côtiéres et en eau peu profonde rejetteront des hydrocarbures et des métaux lourds en concentration suffisante pour entrainer une réduction des prises par suite d'une altération de la saveur et de l'accumulion de métaux lourds.

Les membres de groupe d'étude ont été unanimes pour dire que l'hypothèse n° 13 restait valide et occupait une place relativement importante dans le PSEB, particulièrement en ce qui concerne les ramifications qui vont de l'exposition chronique aux hydrocarburures à la perte de saveur de poisson. Des organismes gouvernementeaux recueillent actuellement des données sur les taux d'hydrocarburers et de métal à l'état de trace qui sont présents dans les sédiments et dans les biotes de plusiers régions de la mer de Beaufort. Le groupre a recommandé que l'on compare ces données afin de déterminer les régions où des doses corporelles élevées d'hydrocarburers et de métal à l'état de trace, présentes dans la faune benthique ou dans le poisson, peuvent être corrélées avec la contamination des sédiments. L'examen des résultats de l'étude du FREE sur l'altération du poisson a également été jugé prioritaire.

Comme au cours de l'atelier précédent, il a été recommandé de soumettre, dans le port de Tuktoyaktuk, la concentration d'hydrocarbures présente dans le poisson à une série de mesures chronologiques. Les participants ont en outre étudié la possibilité de mesurer régulièrement la concentration d'oxyde à fonction mixte présente dans le poisson et ont conclu qu'il aurait plus tard lieu d'en faire un éventuel élément du programme de surveillance recommandé. Aucun programme destiné à surveiller les conséquences précises de l'absorption de métal lourd par le poisson ou d'autres biotes n'a été recommandé. Les participants ont dit s'attendre à ce que l'exercise d'une surveillance destinée à assurer le respect des normes régissant le déversement des résidus pourrait régler les éventuels problèmes engendés par la contamination causée par le métal lourd.

HYPOTHESE N° 14: Les installations aménagées près des côtes altéreront la bande d'eau saumâtre et réduiront la population de corégones tschir.

Deux nouvelles ramifications ont été ajoutés à cette hypothèse pour qu'il soit tenu compte des répercussions qu'une modification de la pente de fond marin pourrait avoir sur les corégones tschir. Des études consacrées à des chaussées construites dans la baie Prudhoe ont révélé que des installations aménagées près des côtes pourraient amener des fluctuations de température et du taux de salinité qui pourraient à leur tour influer sur la répartition des corégones tschir dans la partie sud-est de la mer de Beaufort. On ignore toutefois si de telles modifications de la répartition auraient des répercussions considérables sur l'ensemble des populations des corégones tschir our sur la capture de ces poissons. Les participants ont également estimé qu'un certain nombre de programmes actuellement mis en oeuvre par l'Institute des eaux douces (Pêches et Océans) se rapportaient à une ou à plusieurs des ramification attribuées à cette hypothèse.

Il a été recommandé de procéder à une étude sommaire et générale afin de résumer l'éventail de conditions océanographiques que présente la région côtière de la mer de Beaufort, même si les chaussées ne font actuellement pas partie du scénario de l'exploitation des hydrocarburres adopté à l'échelle régionale. De tels travaux de recherche pourraient d'une part aider à déterminer dans quelle mesure les chaussées pourraient perturber le taux de salinité et la température dans les divers secteurs situés près des côtes et d'autre part contribuer à évaluer la fragilité des corégones tschir dans chacun de ces secteurs. Les participants ont également insisté sur la nécessité d'entreprendre le plus tôt possible des travaux de recherche sur l'océanographie littorale ainsi que sur les mouvements et la répartition du poisson, s'il est finalement décidé de mettre en place des chaussées.

HYPOTHESE N° 15: Les installations aménagées près des côtes perturberont la bande d'eau saumâtre et réduiront la population des ciscos artiques de l'Alaska.

Les participants avaient conclu, au cours du dernier atelier, que les renseignements disponibles ne permettaient pas de confirmer ou d'infirmer les ramifications attribuées à l'hypothèse n° 15; aucune donnée ne permettait non plus de la réfuter globalement. Tandis que les résultats d'enquêtes effectuées récemment près de la chaussée en place dans la baie Prudhoe renforcent l'hypothèse dans son ensemble, une étude entreprise dernièrement sur la côte du Yukon par le ministère des Pêches et océans devrait produire des données relatives à l'une de ses ramifications. En exerçant une surveillance continue sur la pêche de ciscos artiques pratiquée en Alaska (rivière Colville) à des fins commerciales, on apprendra si la chaussée en place à la baie Prudhoe influe ou non sur l'une des ramifications attribuées à cette hypothèse. Le groupe a toutefois qualifié de lacune grave l'insuffisance des données dont on dispose sur la température et le taux de salinité des eaux qui s'étendent sur quelques centaines de mètres à partir du littoral et a recommandé d'insister davantage, dans le cadre des recherches effectuées dans la région, sur la collecte de données relatives à la température, à la salinité ainsi qu'à d'autres facteurs physiques et océanographiques.

Comme pour l'hypothèse n° 14, les participants ont considéré la possibilité que soit mis sur pied un programme de recherche pour évaluer dans quelle mesure les perturbations dans les courants, les températures et les taux de salinité causées par la construction de chaussées peuvent altérer diverses régions depuis le delta du Mackenzie jusqu'à la frontière entre le Canada et les États-Unis. Il a été conclu que la température et le taux de salinité des eaux côtières étaient probablement plus susceptibles d'être perturbés le long du Yukon que de la péninsule de Tuktoyaktuk. C'est pourquoi les participants ont recommandé qu'une étude soit entreprise, sur une petite échelle, pour étudier dans quelle mesure les diverses régions se ressentent différement des changements effectués près des côtes.

HYPOTHESE N° 16: La construction de bases côtières et l'exploitation de réservoirs en eau peu profonde entraineront une diminution de la population de ciscos arctiques et de corégones tschir.

La réévaluation de cette hypothèse au cours de l'atelier se justifiait principalement par la transformation qu'allait éventuellement subir le scénario d'exploitation des hydrocarbures par suite de la mise en place d'une installation de production (c.-à-d. de l'ADGO) dans une région où la profondeur de l'eau est inférieure à cinqu mètres. Bien que les participants aient conclu à la validité de cette hypothèse, ils ont estimé qu'il était très improbable que les débris rejetés par cette installation aient des répercussions notables, étant donné les petites quantités d'effluent auxquelles on s'attend. Il faudrait toutefois réexaminer ultérieurement cette hypothèse ainsi que les besoins de recherche et de surveillance qui se manifesteront peut-être si les quantités d'eau produites dépassent significativement les estimations actuelles.

HYPOTHESE N° 17: Les prises d'eau réduiront les populations des ciscos arctiques et de corégones tschir.

Au cours des deux ateliers (1983 et 1985), cette hypothèse a été jugée extrêmement improbable, car on s'attandait à ce que les besoins en injection d'eau des installations aménagées près des côtes canadiennes soient inférieurs à ceux des installations de l'Alaska. Le groupe a néamoins recommandé d'examiner les résultats du programme de surveillance des États-Unis pour déterminer s'il y avait lieu de réévaluer ultérieurement cette hypothèse.

HYPOTHESE N° 18: Les émissions gazeuses émanent du trafic aérien et maritime de même que des opérations de forage, des plates-formes au large des côtes et des installations côtières altéreront la qualité de l'air.

Au cours de dernier atelier, le groupe a conclu que cette hypothèse était improbable étant donné la quantité prévue d'émissions gazeuses attribuée à l'exploitation des hydrocarbures au large des côtes dans la région de la mer de Beaufort. Aussi n'a-t-on pas réexaminé cette hypothèse dans le cadre des activités du PSEB en 1985.

HYPOTHESE N° 19: Le dragage et le dépôt des matériaux dragués réduiront les populations de phoques barbus.

L'hypothèse n° 19 ayant été établie en dehors des ateliers officiels organisés dans le cadre de la première étape du PSEB, c'est au cours du présent atelier que les ramifications de cette hypothèse ont été soumises à un examen critique. Si on ne s'attendait pas à ce que la mer de Beaufort fasse actuellement — ou ait fait par le passé — l'objet de nombreuses recherches se rapportant directement à cette hypothèse, on a par contre noté qu'il existait pour les autres régions du monde une masse d'information sur les répercussions environnementales du dragage.

Après avoir examiné la validité de chaque ramification, les participants ont conclu, à la lumière des répercussions que les opérations de dragage avaient eues ailleurs dans le monde, et compte tenu de l'importance et de l'emplacement prévus des opérations de dragage nécessaires dans la mer de Beaufort, que cette hypothèse était improbable et ne justifiait pas qu'on la soumette à un test. Il a toutefois été précisé qu'il pouvait y avoir bioaccumulation de certains contaminants (plus particulièrement de métaux lourds) dans le foie des phoques qui se nourrissaient dans les régions où les activités de dragage s'étendaient sur de longues périodes. Les participants ont par conséquent recommandé de mesurer à l'occasion les concentrations en métal lourd présentes dans le foie des phoques barbus, ces substances pouvant compromettre la santé de l'homme.

HYPOTHESE N° 20: Le déversement de débris contaminés par des boues de forage à base d'huile pendant l'aménagement d'installations de production en eau peu profonde entrainera une réduction des populations de ciscos arctiques, de corégones tschir et de corégones de lac; l'accumulation d'hydrocarbures (altération) se traduira également par une diminution des prises de ces poissons.

Cette hypothèse a été élaborée et évaluée au cours de l'atelier de 1985, le scénario de l'exploitation des resources devant changé par suite de l'utilisation possible, en certains cas, de boues de forage à base d'huile. Aux fins de la discussion, les participants ont supposé que des débris contaminés par des boues à base d'huile peuvent ête déversés dans des eaux peu profondes situées près du littoral et fréquentées par des poissons anadromes. Les participants ont considéré le champ de l'ADGO comme étant un exemple caractéristique de site où des débris contaminés par le pétrole pouvaient être déversés.

Après avoir examiné chacune des ramifications attribuées à cette hypothèse, les participants ont conclu que les poissons anadromes pouvaient être contaminés par suite de l'ingestion d'épifaunes benthiques, lesquelles accumulent des hydrocarbures provenant des débris empilés sur le fond marin. Bien que les participants aient jugé cette hypothèse à la fois valide et testable pour ce qui est de sites pris séparément, ils s'attendaient à ce que l'élimination des débris ait des répercussions négligeables sur les populations régionales de ciscos arctiques, de corégones tschir et de corégoes de lac. Les participants ont jugé fortement improbable la partie de cette hypothèse qui aurait comme ramification une diminution de ces espèces.

Comme il n'existe pas de cas bien précis qui pourrait permettre de tester la conclusion susmentionnée, aucun programme de recherche ou de surveillance n'a été recommandé relativement à cette nouvelle hypothèse. Il a toutefois été conclu que lorsque le FREE aura terminé son étude sur l'altération, il faudra en examiner les résultats pour déterminer s'ils influent sur l'une ou l'autre des conclusions tirées par les participants.

SUMMARY

The Beaufort Environmental Monitoring Project (BEMP) was initiated in 1983 by Indian and Northern Affairs Canada and Environment Canada. The program is to provide the technical basis for the design, operation and evaluation of a comprehensive and defensible environmental research and monitoring program to accompany phased hydrocarbon development in the Beaufort Sea. This document is the report of the activities during the second year of the project and contains recommendations for future environmental studies.

The primary activities during 1984-85 were a pre-workshop review of studies initiated since December 1983, preparation of project overviews describing the purpose of these investigations and their relationship to existing BEMP hypotheses, the conduct of a workshop in early February 1985, and the preparation of this report. The workshop itself consisted of a hypothesis-by-hypothesis review of recent and ongoing studies, incorporation of this new information in the existing hypotheses, and preparation of recommendations for further research and monitoring. Due to a change in the development scenario involving the possible use of oil-base drilling fluids, a new hypothesis related to potential impacts of oil-contaminated cuttings discharge on anadromous fish was also formulated and evaluated at the 1985 workshop.

The following is a summary of the conclusions and recommendations that emerged from subgroup discussions of each impact hypothesis. The main body of this report contains a review of new information that was found to be relevant to the various linkages that comprise the BEMP impact hypotheses, as well as the rationale for specific research or monitoring recommendations. Brief overviews of recent and ongoing investigations that were considered relevant to the project are provided in an appendix.

HYPOTHESIS NO. 1: Ship traffic, seismic exploration and active offshore structures will cause a reduction in the western Arctic population of bowhead whales.

A large number of studies relevant to Hypothesis No. 1 have been completed since the previous BEMP workshop. Following a review of these programs, it was concluded that the hypothesis and its associated linkages remain valid. A new linkage was added to the hypothesis during the February 1985 workshop. This link states that "the cumulative effect of all offshore industrial activities will be to create a large-scale zone of bowhead whale exclusion encompassing the entire industrial zone". The link was added to underscore the increasing research emphasis directed at the cumulative effects of hydrocarbon development on bowheads, and at the same time reflect the lower priority assigned to evaluation of short-term, site-specific impacts. There is also further evidence over the last year that annual differences in the distribution of bowheads on their summer range in the southeastern Beaufort Sea may be influenced or determined by a combination of physical and biological factors. Of particular interest are those factors influencing large-scale differences in the distribution and abundance of zooplankton, which are the primary prey of bowhead whales.

The group recommended that the priorities for research and monitoring in 1985 should be placed on: (1) continuation of systematic surveys and studies of long-term behaviour through aerial photography of individual whales, and (2) studies of food distribution and availability (in relation to oceanographic phenomena and bowhead distribution). These research programs will provide the necessary information to determine if some segment of the bowhead population does not occur in the offshore industrial zone, as well as further data on natural factors that may contribute to observed differences in bowhead distribution since systematic surveys were initiated in 1980. Although the subgroup reached a consensus on the need for these two areas of investigation, there were differing viewpoints on specific elements of the strategy or design of each project.

HYPOTHESIS NO. 2: Various facilities and activities associated with offshore hydrocarbon development will affect the white whale harvest.

The workshop participants confirmed the validity of this hypothesis, but concluded that less emphasis should be placed on several of its linkages. In particular, the group expected that delays in ice break-up due to the presence of offshore artificial islands and advanced break-up as a result of icebreaker traffic were both unlikely in view of the present development scenario. Similarly, it was concluded that present levels of ship traffic are unlikely to prevent white whales from entering Mackenzie Estuary, although it may cause local and short-term changes in distribution. Wage employment of hunters in the petroleum industry may change the pattern of hunting, but participants did not expect this to cause a substantial change in the size of the white whale harvest.

Research to determine natural factors influencing white whale distribution in the Mackenzie Estuary was discussed, but it was eventually agreed that such studies are unnecessary at the present time. The rationale for this conclusion was that an adequate data base on white whale distribution patterns already exists and would allow detection of any large changes that may be associated with industry activities. In addition, industry is already committed to the mitigation of perceived concerns related to possible effects of their operations on the white whale harvest. No expansion of the existing white whale monitoring program was considered necessary, and it may be possible to decrease the frequency of this monitoring to once every two or three years.

Workshop participants also recommended continued monitoring of ice break-up, harvest levels and possible interference by industry activities with the white whale harvest.

HYPOTHESIS NO. 3: Marine vessel activities, seismic operations, dredging operations, aircraft overflights and active offshore platforms/artificial islands will reduce the size of ringed and bearded seal populations in the Beaufort Sea.

This hypothesis and its linkages were expected to remain valid, but it was concluded that the cumulative effects of all links would probably be inconsequential or too hard to detect (due to natural variability in population levels) at the present level of industrial activity in the Beaufort region. For example, studies conducted by DFO (Freshwater Institute) each year since 1981 have shown no correlation between low densities of hauled-out seals and proximity to industrial activities. Habitat exclusion resulting from the physical presence of offshore structures and marine vessel traffic were expected to be insignificant at both individual and population levels, while the energetic costs associated with avoidance and diving responses to aircraft overflights would also be inconsequential from a regional perspective.

No specific research or monitoring programs were recommended by the workshop participants to address this hypothesis.

HYPOTHESIS NO. 4: Increased frequency of icebreaker traffic through the landfast ice and through Amundsen Gulf will reduce ringed seal pup production and have subsequent effects on population levels.

After reviewing this hypothesis and its linkages, the workshop participants concluded that it remained valid in the form presented in the 1983-84 BEMP report. However, a fourth link was added to suggest that reduced ringed seal pup production will result in lower population levels, and the hypothesis re-worded to reflect this change. It was concluded that the areas of habitat that may be lost due to icebreaker traffic would be small in relation to the available ringed seal breeding habitat in the region. Direct losses of ringed seal pups in icebreaking corridors would occur, but were expected to be a small proportion of total pup production.

During the link-by-link review of this hypothesis, workshop participants discussed research that would substantially increase understanding of factors affecting ringed seal pup production in Amundsen Gulf and the potential impact on pupping habitat of ice cover destabilization associated with icebreaking. However, it was generally agreed that much of this research would not be possible until some icebreaker traffic occurs in the Gulf. On the other hand, the group recommended continued collection of satellite imagery to provide the basis for future analysis of the relationships between ice conditions and production and survival of ringed seals, and address the question of destabilization of the ice cover due to icebreaker traffic.

HYPOTHESIS NO. 5: Icebreaker traffic in the transition (shear) zone will reduce bearded seal pup production.

Although no research relevant to this hypothesis has been conducted since the last workshop, the group concluded that it remained valid. There is little new information on bearded seal vocalizations and mating behaviour, and the possible effects of icebreaker traffic on these behaviours (i.e., disturbance-related reductions in vocalization rates and masking of calls due to underwater noise). The group concluded that a research program could be designed to determine the direct effects of icebreaker traffic on seal vocalizations, but since these studies are unlikely to provide information on how decreased vocalization rates may affect mating behaviour or success, they were considered a low priority in the context of the present hypothesis.

Icebreaker traffic in the transition zone will result in mortality of some bearded seal pups, but losses were expected to be extremely small given the present development scenario. Because it would be difficult to detect changes in pup production following the anticipated small losses, no research or monitoring was recommended to address this aspect of Hypothesis No. 5.

HYPOTHESIS NO. 6: Icebreaker traffic in Amundsen Gulf will affect ringed seal and polar bear populations.

The complexity and testability of this hypothesis were a subject of much discussion because it encompasses all the trophic levels in the marine ecosystem of Amundsen Gulf, and involves processes and biological resources that are characterized by a high degree of natural variability. Nevertheless, the hypothesis itself was expected to remain valid. Several ongoing research projects by DFO will provide information relevant to one or more of its linkages. Studies of ringed seals (Arctic Biological Station) and polar bears (Canadian Wildlife Service) were expected to result in data that will be useful in evaluation of upper links in the hypothesis. Many of the uncertainties associated with Hypothesis No. 6 related to the limited information on arctic cod and its trophic relationships in the region.

Other than continuation of ongoing research programs related to this hypothesis, no research or monitoring programs directed explicitly at any of its linkages were recommended. However, the workshop subgroup identified two general concerns regarding the availability of fundamental data on ice cover in the Beaufort Sea and Amundsen Gulf. Firstly, the present limited communication between life science specialists and ice scientists was believed to be hampering existing research programs. It was recommended that increased cross-disciplinary contact between these groups be encouraged. The second concern was that no effort is presently being directed at assuring the continued availability of low cost ice data such as daily, full resolution NOAA satellite imagery. The group concluded that attempts should be made to ensure that sea ice data collection and analyses are continued to the extent required for the optimal interpretation of the results of biological studies. Summary catalogs of available imagery should be prepared for future access by researchers in the Beaufort region.

HYPOTHESIS NO. 7: The presence of active facilities will result in increased polar bear mortality.

After examination of this hypothesis and its linkages, the working group concluded that both remained valid. Personnel on drill rigs continue to report the coincidence of bears with offshore structures, although only one problem bear was destroyed in the Beaufort region during the last year. In addition, considerable progress has been made in the development of methods for detecting and deterring bears. Recent research on detection techniques has focused on microwave and infra-red instruments, while polar bear deterrant studies have involved further evaluation of the effectiveness of the rubber bullet gun, plastic slugs fired from a shotgun, and sound-producing devices.

The participants in the 1985 workshop re-confirmed support for research on polar bear detection and deterrant techniques, as well as the possible use of certain detection instrumentation for the censusing of marine mammals. A study to examine potential sex- or age-specific variablity in the attraction or avoidance responses of polar bears was discussed by the group, but was eventually considered unnecessary at the present level of hydrocarbon development in the region. However, there was considerable concern regarding the unknown status of the Alaskan subsistence polar bear harvest, which is focused on females with cubs. In the absence of appropriate data on this harvest, it was emphasized that declining numbers of polar bears in the Beaufort region might be incorrectly attributed to either the Canadian harvest or industrial impacts.

HYPOTHESIS NO. 8: Offshore development activities will reduce the harvest of polar bears.

Participants in the previous workshop concluded that this hypothesis was unlikely, and therefore, did not warrant any specific research or monitoring. The present group agreed with this overall conclusion and recommendation at the current level of industrial activity in the Beaufort Sea. During the period when polar bears are harvested, icebreaker tracks would quickly re-freeze and are unlikely to impede hunter travel over the landfast ice.

However, as in the previous hypothesis, the group concluded that any future monitoring efforts would be hampered by the lack of data on the Alaskan subsistence harvest of polar bears. Participants indicated that without adequate information on this hunt, it will not be possible to determine the factors responsible for any future declines in total numbers of polar bears.

HYPOTHESIS NO. 9: Chronic/episodic oil spills resulting from normal hydrocarbon development activities within and adjacent to the marine environment will result in localized mortality of polar bears.

Information presented by petroleum industry representatives in the workshop subgroup re-examining this hypothesis indicated that chronic oil spills associated with exploration activities are both infrequent and relatively small. Nevertheless, research conducted with captive polar bears has shown that this species is extremely sensitive to oil contact and/or ingestion. As a result, the present group endorsed and encouraged the publication and implementation of an "Action Plan for Protection of Polar Bears in the Event of a Major Oil Spill", which has been prepared by federal, territorial and provincial polar bear biologists.

Workshop participants also recommended development of a plan that would allow effects monitoring of "spills of opportunity". Such a plan should (1) identify a scientific team to respond to spills, and (2) provide a description of what and how monitoring should be initiated (including associated research) in the event of a spill. Although it was recognized that the Polar Bear Oil Spill Action Plan should be released in the near future, the group concluded that revisions to this or other plans may be necessary at a later date to address opportunistic research/monitoring, as well as to consider other species of marine mammals. It is also important that the existing Action Plan be reviewed by the oil industry as soon as possible to allow proper integration of its contents into present oil spill contingency plans for the Beaufort region.

A research program to determine the behavioural responses of polar bears to oil-covered waters and oil-contaminated prey was discussed during the workshop. However, it was concluded that this research would encounter considerable opposition and, therefore, was considered untenable at present.

HYPOTHESIS NO. 10: Chronic (episodic) oil spills resulting from normal hydrocarbon development activities within and adjacent to the marine environment will result in local mortality of certain species of birds.

This hypothesis was combined with Hypothesis No. 11 during the 1985 workshop, because it was concluded that the latter was simply a specialized case of a more general hypothesis related to the effects of chronic oil spills on bird populations. Several of the original linkages in Hypothesis No. 11 were considered invalid or improbable and, therefore, were removed during this consolidation.

Much of the discussion in the workshop focused on the need to monitor and record the incidence of oiled birds (or other wildlife) to document the effects of incidental oil spills. Consensus was not reached on this question, largely because there have been no reports of bird mortality to date following chronic spills in the region and this is not an area of significant concern in other oil producing regions of the world.

It was concluded that oil spill reports should continue to include any observations of oiled wildlife. With possible future hydrocarbon production, chronic oil spills may increase in frequency and volume from present levels, and this may then justify implementation of a systematic monitoring program. Information provided by the oil industry during and after the workshop indicated that a total of 38 spills occurred in the 1984-85 drilling season, and that most of these events involved relatively small losses of oil.

HYPOTHESIS NO. 11: Oil slicks in open water areas around offshore structures during normal periods of ice cover will cause increased mortality of eiders and diving ducks.

This hypothesis was combined with Hypothesis No. 10 during the workshop, and no longer exists in its original form.

HYPOTHESIS NO. 12: Frequent low altitude aircraft flights over staging brant will cause increased overwinter mortality.

During the previous BEMP workshop, it was concluded that this hypothesis was invalid. Consequently, it was not re-evaluated this year.

HYPOTHESIS NO. 13: Shorebases and shallow-water production facilities will release hydrocarbons and heavy metals at sufficient levels such that fish harvest will be reduced through tainting and heavy metal accumulations.

The consensus of the working group was that Hypothesis No. 13 remained valid and an area of relatively high profile with respect to BEMP, particularly those links leading from chronic hydrocarbon exposure to the tainting of fish. Federal government agencies are presently collecting data on hydrocarbon and trace metal levels in sediments and biota in several areas of the Beaufort Sea. The group recommended comparative analyses of the data from these studies to identify any areas where elevated body burdens of trace metals and hydrocarbons in benthic fauna or fish can be correlated with contamination of sediments. Review of the results of the ESRF study on tainting was also considered a priority.

As in the previous workshop, it was recommended that a program of time series measurements of hydrocarbons in fish be initiated in Tuktoyaktuk Harbour. The possible routine measurement of mixed-function oxidase (MFO) activity in fish was also examined and concluded to be worth future consideration as a potential component of the recommended monitoring program. No specific effects monitoring programs for heavy metal uptake by fish or other biota were recommended. Participants expected that potential concerns related to heavy metal contamination could be adequately addressed through standardized compliance monitoring of waste discharges.

HYPOTHESIS NO. 14: Nearshore structures will disrupt the nearshore band of brackish water and reduce the broad whitefish population.

Two new links were added to this hypothesis to include consideration of the effects of changes in the slope of the sea bottom on broad whitefish. Recent studies of causeways in Prudhoe Bay indicate that nearshore structures could cause changes in temperature and salinity regimes that subsequently affect the distribution of broad whitefish in the southeastern Beaufort Sea. However, it is not known if such changes in distribution would have significant implications to broad whitefish populations or their harvest. A number of research programs that are being conducted by the Freshwater Institute (DFO) were also considered relevant to one or more of the linkages in this hypothesis.

A brief, broadly based study to summarize available information on the range of coastal oceanographic conditions present in the Beaufort Sea was recommended, even though causeways are not presently part of the regional hydrocarbon development scenario. Such research would aid in evaluation of the potential for causeways to disrupt nearshore temperature/salinity patterns in different subareas and the vulnerability of broad whitefish in each subarea. The group also emphasized the need to initiate research on nearshore oceanography and fish distribution and movements as soon as possible if causeways are eventually envisioned.

HYPOTHESIS NO. 15: Nearshore structures will disrupt the nearshore band of brackish water and will reduce the Alaskan population of arctic cisco.

As in the last workshop, the present group concluded that the links in Hypothesis No. 15 could not be proved or disproved on the basis of existing information, and there was no evidence for rejection of the overall hypothesis. The results of recent investigations conducted near the Prudhoe Bay causeway strengthened the overall hypothesis, while a recently initiated DFO study on the Yukon coast is expected to provide information relevant to one of its links. The continued monitoring of the Alaskan commercial arctic cisco fishery in the Colville River will also provide evidence on whether or not arctic cisco migrations are being affected by the existing causeway in Prudhoe Bay. However, the group identified the lack of T/S data within a few hundred metres of the coastline as a particularly serious information deficiency and, therefore, recommended increased emphasis on collection of temperature, salinity and other physical oceanographic data during biological field research in this region.

As in Hypothesis No. 14, participants discussed a research program to assess the vulnerability of different areas from the Mackenzie Delta to the U.S./Canadian border to disruptions in current, temperature and salinity regimes from causeway construction. It was concluded that the potential for disruption of nearshore T/S patterns is probably greater along the Yukon coast than along the Tuktoyaktuk Peninsula. As a result, a low level study to examine regional differences in vulnerability of different areas to shoreline modifications was recommended.

HYPOTHESIS NO. 16: The construction of shorebases and development of shallow-water production fields will result in a decrease in the populations of arctic cisco and broad whitefish.

The major rationale for re-evaluation of this hypothesis in the present workshop was a potential change in development scenario involving the siting of a production facility (i.e., ADGO) in an area where the water depth is < 5 m. Although participants concluded that the hypothesis was valid, significant impacts of production waste discharges from this field were considered extremely unlikely due to the small volumes of effluent expected. However, the hypothesis and possible research/monitoring needs should be re-examined in the future if anticipated volumes of produced water increase substantially from present estimates.

HYPOTHESIS NO. 17: Water intakes will reduce populations of broad whitefish and arctic cisco.

In both the 1983 and 1985 workshops, this hypothesis was considered extremely unlikely because the waterflood requirements in Canadian nearshore fields were expected to be small compared to those of the Alaskan fields. Nevertheless, the group did recommend review of the U.S. monitoring program results to determine if this hypothesis should be re-evaluated at some future date.

HYPOTHESIS NO. 18: Air emissions resulting from the operation of aircraft, marine vessels, drill rigs, offshore platforms and shorebases will adversely affect air quality.

During the last workshop, it was concluded that this hypothesis was unlikely given the anticipated quantities of air emissions associated with offshore hydrocarbon development in the Beaufort region. Consequently, it was not re-examined during the 1985 BEMP review.

HYPOTHESIS NO. 19: Dredging and deposition of dredge spoil will reduce the bearded seal population.

Since Hypothesis No. 19 was prepared outside of the formal workshops during Phase 1 of BEMP, the current workshop was the first time that the linkages have been subjected to critical review. Although few recent or ongoing research programs in the Beaufort region were expected to be directly relevant to this hypothesis, it was noted that a great deal of information on the environmental effects of dredging is available for other geographic areas in the world.

Following a review of the validity of each linkage, workshop participants concluded that, on the basis of worldwide experience regarding the effects of dredging operations and the anticipated intensity and locations of dredging required in the Beaufort Sea, this hypothesis was unlikely and did not justify testing. However, it was stated that bioaccumulation of some contaminants (particularly heavy metals) could occur in the livers of individual bearded seals if they fed in areas of active dredging for extended periods. Consequently, measurement of heavy metal concentrations in bearded seal livers was recommended on an opportunistic basis because of the possible link to human health.

HYPOTHESIS NO. 20: The discharge of cuttings contaminated with oil-base drilling muds during the development of shallow-water production facilities will reduce populations of arctic cisco, broad whitefish and lake whitefish, and will also decrease the harvest of these species due to hydrocarbon accumulation (tainting).

This hypothesis was developed and evaluated during the 1985 workshop because of a change in the development scenario that may involve use of oil-base drilling muds for certain applications. For the purpose of the group's discussion, it was assumed that cuttings contaminated with oil-base mud may be discharged in shallow nearshore waters used by anadromous fish species. The ADGO field was assumed to be a typical nearshore site where oil-contaminated cuttings might be discharged.

Following a link-by link review of the hypothesis, it was concluded that tainting of anadromous fish could occur as a result of the ingestion of benthic epifauna that accumulate hydrocarbons associated with cuttings piles on the sea floor. Although this aspect of Hypothesis No. 20 was considered both valid and testable from a site-specific perspective, it was expected that effects of cuttings disposal on the regional populations of arctic cisco, broad whitefish and lake whitefish would be insignificant. The portion of the hypothesis involving links that lead to decreased abundance of the populations of these species was judged to be highly improbable.

In the absence of a site-specific case upon which to test the above conclusion, no research or monitoring was recommended in relation to this new BEMP hypothesis. However, it was concluded that the results of the ongoing ESRF tainting study should be reviewed when available to determine if they would affect any of the conclusions of the present group.

INTRODUCTION

During 1983, Indian and Northern Affairs Canada and Environment Canada initiated the Beaufort Environmental Monitoring Project (BEMP). The program is to provide the technical basis for the design, operation and evaluation of a comprehensive and defensible environmental research and monitoring program to accompany hydrocarbon development in the Beaufort Sea relative to the regulatory responsibilities of the sponsoring departments. BEMP was considered necessary because of: (1) environmental concerns regarding this development; (2) uncertainties associated with Environmental Impact Assessment (EIA); and (3) the need for a research and monitoring plan that is fully integrated with ongoing exploration and future production activities. In the Final Report of the Beaufort Sea Environmental Assessment Panel (FEARO 1984), the need for research and monitoring programs to accompany phased oil and gas development in the region was emphasized. In this regard, the Panel commended Indian and Northern Affairs Canada and Environment Canada on their initiative in sponsoring the Beaufort Environmental Monitoring Project.

In 1985, a comparable program has been initiated to determine research and monitoring priorities related to possible effects of hydrocarbon development and transporation in the Mackenzie Delta and Valley regions. This program is referred to as the Mackenzie Environmental Monitoring Project (MEMP), is following procedures similar to those employed in BEMP, and is jointly funded by Indian and Northern Affairs Canada, Environment Canada, Fisheries and Oceans Canada, and the Governments of the Northwest Territories and Yukon.

This document is the report of activities during the second year of BEMP. It reviews the results of recent and ongoing studies and provides recommendations for future research and monitoring on the basis of this new information. In addition, the report summarizes the activities that occurred during the first year of BEMP, and describes the process and mechanism through which BEMP participants will provide recommendations on the direction of future research and monitoring programs. The first year of BEMP (1983-84) is referred to as Phase I, and the second year (1984-85) as Phase II.

During Phase I, BEMP proceeded through two interdisciplinary workshops and a series of technical meetings that were attended by experts and resource managers from government, industry, universities and the consulting community. The objective of the first year of the project was to develop a plan for initiating research and monitoring activities. This plan was to: (1) address those impacts that could be most significant if they occurred; (2) be based on current understanding of industrial development scenarios and ecological processes in the region; (3) be capable of responding to altered development scenarios and new information regarding ecological processes; and (4) represent the majority viewpoint of a range of disciplinary specialists with experience in research and environmental management in the Beaufort Sea region.

For BEMP, *monitoring is defined as a test of an impact hypothesis designed to (a) measure environmental impacts; and (b) analyse cause-effect relationships.* As such, monitoring is a scientific process designed to test specific hypotheses linking sources of environmental impact (actions) to their expression in the environment. On the other hand, *research is a test of a process hypothesis, or baseline measurements required to increase fundamental knowledge regarding the physical and biological environment.*

As background to Phase II, the major activities that occurred during the first year of BEMP are briefly summarized below. The purpose, activities and results of Phase II are described in subsequent sections.

OVERVIEW OF PHASE I

The project employed the overall approach of adaptive Environmental Assessment and Management described by Holling (1978). A brief summary of this phase of BEMP is provided below, while full details are given in the 1983-1984 Final Report for the project.

First Workshop

A number of tasks were completed at the first workshop including determination of the project boundaries, selection of Valued Ecosystem Components (VECs), description of the hydrocarbon development scenario, and development of a simple simulation model.

The geographical extent of the project was defined as extending from Amundsen Gulf to a seaward extension of the Alaska-Yukon border. A line projected westward from the northwestern tip of Banks Island was used to delineate the northern boundary, while the landward extent of the study area was limited to 2 km inland within the Mackenzie Delta, and to the level of storm surges elsewhere. The temporal horizon of the development scenario was set at 30 years.

VECs were defined as *resources or environmental features that: (1) are important to local human populations; or (2) have national or international profiles; and (3) if altered from their existing status, will be important in evaluating the impacts of development and in focusing management or regulatory policy.* The identification of VECs focused the discussion of research and monitoring programs on those resources and supporting physical processes that are of greatest concern with respect to hydrocarbon development in the region. The final Valued Ecosystem Components determined by workshop participants during Phase I of BEMP were air quality and the population, harvest and available habitat for:

- bowhead whale
- white whale
- ringed seal
- bearded seal
- polar bear
- common eider
- king eider
- diving ducks (oldsquaw, scoters, scaups)
- thick-billed murre
- brant
- lake whitefish
- broad whitefish
- least cisco
- arctic cisco
- arctic char

A development scenario involving four offshore production islands, a peak production rate of 100,000 bbls d^{-1} and transport for crude oil out of the region in two icebreaking tankers was eventually selected as the most suitable scenario for BEMP (based on information provided by workshop participants from the petroleum industry). Changes to this scenario since the last workshop are described in the section describing BEMP activities in 1984-85. Throughout Phase I, it was assumed that production facilities would not be located in waters less than 5 m deep, and that formation cuttings contaminated with oil-base drilling muds would not be discharged to the marine environment.

The simulation model was not developed or utilized for predictive purposes. Its value to the project was its actual construction, which required workshop participants with specialized disciplines to think in interdisciplinary and quantitative terms about the possible interactions between the development scenario and the environment. These relationships were represented by a network of linkages, interconnecting detailed components of the development scenario, and components of the biological, physical and chemical environment with the identified Valued Ecosystem Components.

At a number of subsequent technical meetings, impact hypotheses were developed utilizing the linkages established between industrial activities and VECs. Some of these hypotheses involved only one or two linkages, while others involved complex food web interactions with several linkages. During the technical meetings, linkages in the model were further refined and the number of impact hypotheses

reduced to those considered most plausible given the existing development scenario. However, it is emphasized that the 21 hypotheses eventually selected for evaluation at the second workshop encompass a considerably larger number of perceived concerns associated with Beaufort hydrocarbon development by virtue of the multiple linkages involved in most of the hypotheses.

Workshop to Evaluate Impact Hypotheses

The second BEMP workshop involved 47 participants and was held in Victoria, B.C. from November 28 to December 2, 1983. Each impact hypothesis was reviewed and, modifications to the hypothesis structure and associated linkages were completed. At this time, one additional hypothesis related to dredging was added. Each hypothesis was then critically evaluated by a working group, and a monitoring program was proposed in those cases where the hypothesis was considered valid and important to test. The working groups differed from the discipline-specific modelling subgroups of the first workshop, and were restructured daily to include a cross-section of expertise relevant to all aspects of the hypothesis under discussion.

Five steps were involved in the evaluation of each impact hypothesis:

1. **Clarification of the Hypothesis:**

   This step involved reaching a consensus within the working group regarding the structure of the hypothesis and, if necessary, restatement of the hypothesis or its associated linkages.

2. **Documentation of Existing Knowledge:**

   The following information was documented for each of the linkages comprising a hypothesis:

   - evidence for and against;
   - uncertainties; and
   - other potentially useful information.

3. **Conclusion:**

   On the basis of discussions in the above step, the working group then arrived at one of four conclusions for a given impact hypothesis:

   - it was extremely unlikely and would not justify testing;
   - it was possible, but too difficult to detect;
   - more information was required before a monitoring plan could be designed; or
   - it should be tested with a detailed monitoring plan.

4. **Monitoring and Research:**

   If the subgroup agreed that one of the latter two conclusions was true, a discussion of recommended research and/or monitoring was initiated. Research generally fell into one of three categories: that necessary to (1) provide the information required to determine if monitoring is justifiable, (2) allow design of a monitoring program, and (3) aid in interpretation of the results of a monitoring program.

5. **Documentation:**

   The discussion, conclusions and recommendations of the working groups were summarized by a "recorder" assigned to each group. These summaries were, in most cases, word-processed at the end of each day, circulated to the working group participants for review and comment, and then eventually formed the framework for the 1983-84 BEMP Final Report (Indian and Northern Affairs Canada and Environment Canada 1984).

Phase I BEMP Conclusions and Recommendations

A total of 19 impact hypotheses were evaluated in detail during the first year of the Beaufort Environmental Monitoring Project, while an additional three hypotheses related to resource harvesting were posed but not discussed in the 1983-84 BEMP report. At that time, monitoring programs were recommended in relation to six of the 19 hypotheses, while monitoring was expected to be necessary for four additional hypotheses depending on the results of recommended research or possible changes in the hydrocarbon development scenario. Recommendations for continuation of ongoing research programs or initiation of new research were also provided for six of the 19 hypotheses evaluated during Phase I of BEMP.

PHASE II OF BEMP

Purpose

The long-term success of BEMP depends on its ability to change, to reflect new information gained from ongoing investigations, and to respond to changes in the development scenario. During this and successive years of the project, some hypotheses developed during 1983-84 will require refinement or re-evaluation as this new information provides evidence that some of the linkages are either stronger or weaker than originally expected, and other linkages, impact hypotheses and Valued Ecosystem Components become evident through ongoing research and monitoring activities or due to specific changes in development plans for the region. A strategy for assuring that the BEMP process is both *adaptive* and *iterative* is an alternating two-phase program. The first phase, such as that in the initial year, involves a workshop focusing on system dynamics, following by several technical meetings, and then a second workshop directed at a series of impact hypotheses. During the second phase, annual workshops and associated technical meetings have the following overall purpose:

> **To review and synthesize the existing body of information in order to provide recommendations on progress towards achievement of established research and monitoring objectives (existing hypotheses and linkages), changes to hypotheses, and changes in the direction of the recommended research and monitoring programs.**

The cycle would then return to Phase I activities after 4 to 5 years with a workshop designed to re-examine current understanding of system dynamics, re-establish Valued Ecosystem Components and produce a simulation or conceptual model relating the VECs to the industrial development scenario at that time. A significant change in the development scenario could also trigger a return to Phase I before the end of the 4 to 5 year period.

Introduction of New Hypotheses and VECs

Constraints have been placed on the scope of BEMP research and monitoring recommendations in a number of ways. Two of the most important constraints are the list of VECs and the impact hypotheses. Unless research and monitoring are related to a hypothesis which involves one or more VECs, it will not be included in the recommendations of BEMP participants. Therefore, it is important to periodically review the list of VECs and the hypotheses to ensure that BEMP responds to changing priorities and new information and understanding. Two kinds of responses are envisioned:

1. As described above, the full Phase I procedure will be repeated every 4-5 years. This will ensure that there is a thorough re-examination of the judgements that limit the scope of BEMP (time, space, VECs, hypotheses).

2. During this phase of the project, a procedure has been developed for the introduction of new VECs and new impact hypotheses. New VECs can only be proposed by submission of a statement of specific rationale and supporting evidence to the BEMP Management Committee. At present, such proposals should be submitted to:

Dr. Wayne Duval
Chairman, BEMP Management Committee
c/o ESL Environmental Sciences Limited
34-1035 Richards Street
Vancouver, B.C. V6B 3E4

If the committee agrees that the proposed VEC meets the criteria identified earlier, impact hypotheses would be developed and evaluated at the following BEMP workshop. New hypotheses involving existing VECs can be proposed prior to or at the beginning of a workshop.

It is expected that new hypotheses will be proposed on a regular basis as plans for hydrocarbon development in the Beaufort region evolve and become more refined. A new hypothesis was evaluated a at the 1985 BEMP workshop as a result of a change in the development scenario described later. On the other hand, acceptance of new VECs is expected to occur infrequently, since a large number of potential VECs were examined during the first BEMP workshop (May 1983) and the present list is expected to fully encompass those VECs which meet the necessary criteria. A new VEC was also proposed this year, and the submission to and response of the BEMP Management Committee are included in Appendix C.

BEMP Activities in 1984-85

BEMP activities during 1984-85 consisted of: (1) a review of research and monitoring projects initiated since the last BEMP workshop in December 1983, (2) determination of the potential relationship of each of these programs to the existing BEMP hypotheses and their associated linkages, (3)preparation of brief Project Overviews for each program that may provide information relevant to the existing hypotheses and VECs, (4) planning and invitation of participants for the annual BEMP workshop, (5) conduct of the 1984-85 BEMP workshop, and (6) preparation of this report.

Project Overviews

The project overviews that were provided to each participant prior to the workshop are included in Appendix A of this report.

1984-85 BEMP Workshop

The workshop to evaluate ongoing research and monitoring relevant to the BEMP impact hypotheses, and provide recommendations for future research and monitoring was held from February 5-8, 1985 at the Royal Oak Inn in Victoria, B.C. Participants attending this workshop are listed along with their research interests in Appendix B. The workshop consisted of a hypothesis-by-hypothesis review of research and monitoring that was completed or initiated since the last BEMP workshop. The focus of the review and evaluation process for ongoing research and monitoring was: (1) to incorporate new information in the existing BEMP hypotheses, and (2) to provide recommendations for future directions to research and monitoring based on this new information. Each working group addressing a specific hypothesis included a workshop facilitator and a designated recorder. As in the case of previous BEMP workshops, discussions of the working groups were usually word-processed at the conclusion of each day and provided to participants for review during the course of the workshop. Not all of the 19 hypotheses described in the 1983-84 BEMP report were reviewed during the 1985 workshop. The original hypotheses dealing with the effects of aircraft on staging brant (Hypothesis No. 12) and the effects of various emissions associated with offshore industry operations on air quality (Hypothesis No. 18) were not re-examined this year. This was because the former hypothesis was concluded to be invalid during the previous BEMP workshop, while the latter hypothesis was considered unlikely given the projected air emissions.

Workshop Procedures

At the February 1985 workshop, participants were assigned to interdisciplinary subgroups to review the hypotheses that emerged from Phase I of BEMP. The following steps were followed during the review of each hypothesis:

1. The origin, links, past conclusions and recommendations for research and monitoring related to the hypothesis were reviewed.
2. The results of recent studies (both completed and ongoing) that provide information relevant to each hypothesis link were reviewed.
3. Each link was evaluated in the context of this new information to assess:
   (a) changes in interpretation;
   (b) implications to future research and monitoring; and
   (c) implications to the overall hypothesis, including the alteration, addition or consolidation of links.
4. The overall hypothesis was evaluated in terms of the need for future research and monitoring.
5. Opportunities for integration and coordination of studies to maximize collection of information relevant to the hypothesis and its associated linkages were discussed.

Changes in the Hydrocarbon Development Scenario

As discussed in an earlier section, in order for BEMP to be adaptive and iterative, it must be capable of responding to changes in the hydrocarbon development scenario for the Beaufort region. Since the last workshop in December 1983, there have been two significant possible changes to the development scenario:

1. In the previous BEMP workshop, it was assumed that offshore production facilities would not be located in waters less than 5 m deep. This assumption is no longer valid because of current interest in production from the ADGO field, which is located in the nearshore zone where water depths range from 2-3 m. Although the petroleum industry presently has no plans to incorporate nearshore structures such as jetties or causeways with this or other shallow-water production facilities, it was assumed for the present workshop that such structures could be proposed in the future.
2. The use of oil-base drilling fluids is now contempated for some exploration and development drilling applications in the Beaufort Sea. Therefore, it has been assumed that cuttings contaminated with oil may be discharged as part of routine operations in the region.

In addition, the development scenario originally utilized involved an initial transportation mode of two icebreaking tankers. Recently there has been a revival of interest in a Mackenzie Valley pipeline as a probable first step in a phased development of Beaufort Sea oil. Nevertheless, a combined tanker/pipeline scenario remains a distinct possibility. Additional hypotheses may be necessary to address issues associated with the sub-sea pipeline sections associated with this scenario. The terrestrial issues are being reviewed through MEMP.

New Hypotheses and VECs

Due to a change in the development scenario involving the possible use of oil-base drilling fluids, a new hypothesis was developed and evaluated at the February 1985 workshop related to the potential impacts of oil-contaminated cuttings discharge on anadromous species of fishes. This hypothesis is discussed in detail in a subsequent section (see Hypothesis No. 20).

A proposal to add the coastal zone to the list of VECs was also received at the workshop and has since been evaluated by the BEMP Management Committee. For reasons described in Appendix C, the committee has rejected this proposal.

LITERATURE CITED

FEARO 1984. Beaufort Sea Hydrocarbon Production and Transportation Proposal: Report of the environmental assessment panel. Federal Environmental Assessment Review Office, Hull, Quebec. 146. pp.

Holling, C.S. (ed.). 1978. Adaptive environmental assessment and management. John Wiley and Sons, New York. 377 pp.

Indian and Northern Affairs Canada and Environment Canada. 1984. Beaufort Environmental Monitoring Project 1983-84 Final Report. Unpubl. Rept. prepared by LGL Limited, ESL Environmental Sciences Limited and ESSA Limited. 292 pp.

HYPOTHESIS NO. 1

SHIP TRAFFIC, SEISMIC EXPLORATION AND ACTIVE OFFSHORE STRUCTURES WILL CAUSE A REDUCTION IN THE WESTERN ARCTIC POPULATION OF BOWHEAD WHALES

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INTRODUCTION

A substantial number of research programs relevant to this hypothesis have been conducted since the last workshop, and many of these studies were research and monitoring priorities described in the 1983-84 BEMP report.

Much of the discussion during the present workshop was directed at the use of 1984/85 research results to provide an improved definition of the impact hypothesis. It was the consensus of the group that less emphasis should be placed on short-term, site-specific effects of hydrocarbon development on bowhead whales. It was agreed that: (1) effects related to the presence of drilling platforms (Link 1) or ship movements (Link 2) would occur over very limited areas, and (2) relatively definitive results are not available as a result of five years of research on short-term behavioural responses of bowheads to various disturbance sources. In contrast, any cumulative impacts of hydrocarbon development could occur over a longer time frame and a much larger geographic area. It was therefore concluded that continued high priority should be directed towards studies of the cumulative effects of offshore industrial activities in the creation of a large scale zone of bowhead whale exclusion that encompasses the industrial zone within the Canadian Beaufort Sea. This concept was introduced in the Phase I BEMP workshops but was not formally stated as a linkage until the present workshop.

As a result of the reduced emphasis on site-specific effects, a new link (1a) was added to Hypothesis No. 1 (as shown in Figure 1-1) to underscore the importance of potential cumulative effects in contrast to the site-specific interactions implicit in Link 1.

A considerable amount of discussion during the 1985 workshop was directed at the difficulties in distinguishing between changes in bowhead whale distribution that may result from industrial activities versus those caused by natural factors, particularly oceanographic conditions and their influence on zooplankton distribution and abundance. In this context, it was considered appropriate to restate key aspects of the impact hypothesis in terms of the natural variability in whale distributions that may be associated with food availability:

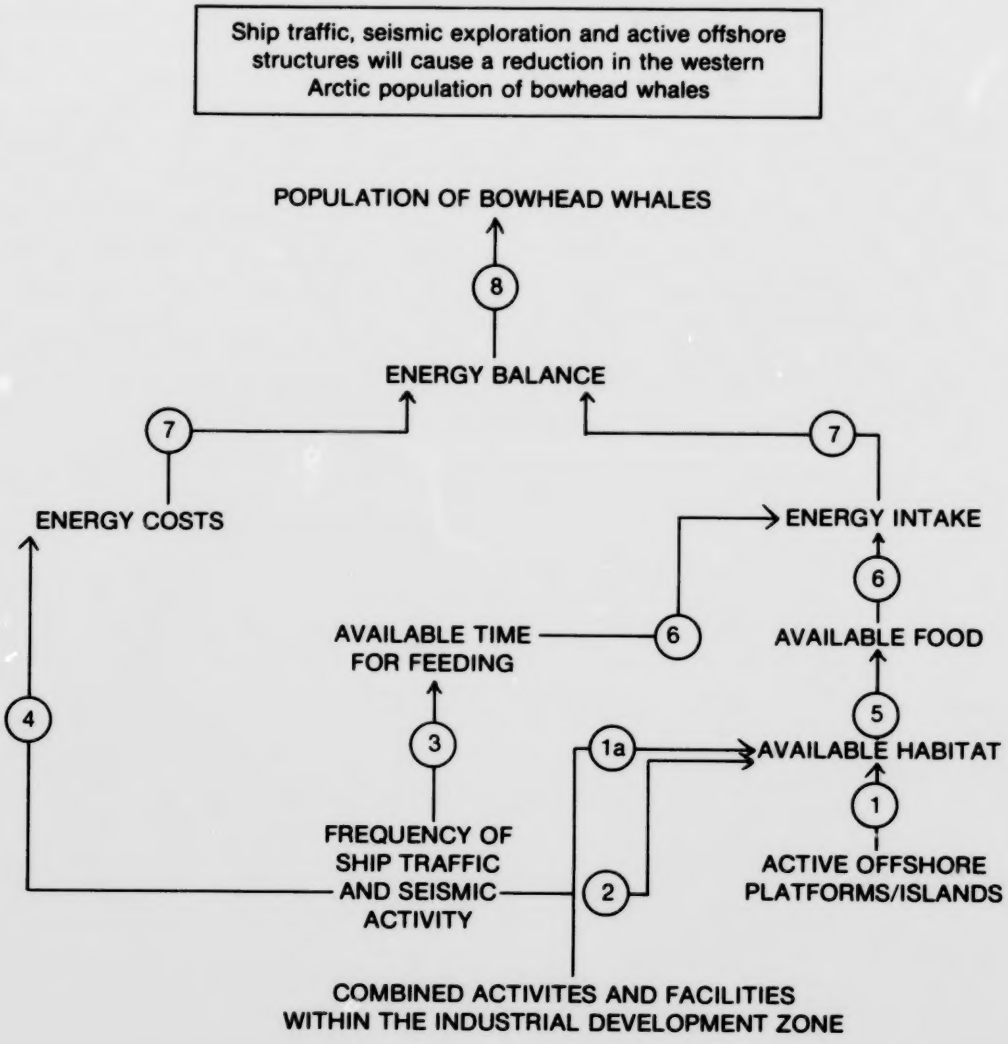
a) The summer distribution of bowhead whales in the eastern Beaufort Sea is closely related to the distribution of "patches" of extremely high densities of zooplankton;

b) Disturbance due to industrial development will reduce the availability of these zooplankton patches to bowhead whales; and

c) A decrease in the availability of zooplankton patches of sufficiently high density will create an energy deficit and resultant decrease in the size of the bowhead whale population.

FIGURE 1-1

POTENTIAL EFFECTS OF SHIP TRAFFIC, SEISMIC EXPLORATION AND ACTIVE OFFSHORE STRUCTURES ON BOWHEAD WHALES



Linkages

1a. The cumulative effect of all offshore industrial activities will be to create a large-scale zone of bowhead whale exclusion encompassing the entire industrial zone.*

1. Each active offshore island or platform will exclude bowheads from a zone around the island/platform.

2. Ship traffic will exclude bowheads from a zone around the ship track.

3. Each passage of a ship will reduce the feeding time available to bowheads.

4. Each passage of a ship will increase the energy expenditure of whales due to avoidance behaviour.

5. The available aquatic habitat determines the level of available food.

6. The amount of available food and the time available for feeding determine the energy intake.

7. Energy intake and expenditures determine the energy balance of a bowhead whale.

8. The energy balance of a bowhead whale determines its survival and its ability to reproduce.

* This hypothesis link was added to more clearly represent the emphasis on the cumulative impact of hydrocarbon development on bowhead whales.

This simplified version of Hypothesis 1 proved helpful in focusing discussion of recommendations for 1985-86 research and monitoring. The group experienced some difficulty in reaching a consensus on all aspects of the recommended research and monitoring strategy. The points over which substantive disagreements occurred are indicated later in this report section. Comments received from participants on a preliminary draft of the report were also useful in clarifying some of the issues and in delineating the points on which a consensus was not reached during the workshop.

REVIEW OF LINKAGES AND RELEVANT RESEARCH

A large amount of research relevant to this hypothesis was reviewed and discussed at the 1985 workshop. The group considered this research on a project by project basis, rather than by linkage as completed for other hypotheses. This approach was considered most practical given the number of projects that were relevant to the new hypothesis link, and the fact that the senior investigators in almost all research programs were present at the workshop to describe the results of specific projects. However, for the sake of consistency with other report sections, the following review and discussion has been presented by link.

Link 1a: The cumulative effect of all offshore industrial activities will be to create a large-scale zone of bowhead whale exclusion encompassing the entire industrial zone.

A number of studies conducted in 1984/85 were useful in evaluating the validity of Link 1(a). Some of these programs were initiated as a result of the 1984 BEMP recommendations. A list of the relevant research titles and their overview numbers in Appendix A follows:

OVERVIEW NO.	TITLE/INVESTIGATORS
1	1984 Beaufort Sea Bowhead Whale Monitoring Study. Harwood and Borstad. 1985
1	Satellite Imagery Component of the 1984 Beaufort Sea Bowhead Whale Monitoring Study. Harwood and Borstad. 1985
2	Factors Determining Bowhead Whale Distribution in the Beaufort Sea: A Feasibility Study. Davis et al. 1985
3	Long-term Effects of Offshore Industrial Activities on Bowhead Whales in the Canadian Beaufort Sea. Davis et al. 1985
33	Water Colour and Temperature in the Southern Beaufort Sea: Remote Sensing in Support of Ecological Studies of the Bowhead Whale. Borstad. 1984

A brief description of the research related to Link 1(a) follows:

Two projects conducted in 1984 directly documented the summer distribution of bowhead whales in the southeastern Beaufort Sea. These were the 1984 Beaufort Sea Bowhead Whale Monitoring Study (Harwood and Borstad 1985), and the photographic component of the study of the Long-term Effects of Offshore Industrial Activities (Davis et al. 1985). These programs are described in greater detail in Appendix A (see Project Overviews 1 and 3, respectively).

The purpose of the systematic aerial surveys (Harwood and Borstad 1985) was to determine the relative abundance and distribution of whales in August/September, and was the fifth consecutive year of such research. As in 1982 and 1983, few whales were recorded in the industrial zone compared to numbers observed in 1980 and 1981. Also, as in past years, bowheads were concentrated in specific areas, particularly in Franklin Bay, close to the Yukon Coast and along the western edge of the Mackenzie plume. The results of the satellite imagery component of the 1984 aerial surveys are described later in this section.

The photographic project (Davis et al. 1985) confirmed the results of the systematic surveys in terms of the distribution of bowheads in the region. Preliminary results of this research also showed that the congregations of whales along the Yukon coast and along the plume edge north of Shingle Point consisted primarily of small animals, as were those in the southern part of the main industrial zone off the Mackenzie Delta. Large animals were found primarly outside of the industrial zone, both to the north of and within Franklin Bay. The authors have concluded that the smaller animals were probably yearlings, while the larger animals were adults and subadults. This study suggests that there was a size/age-specific distribution of bowheads in the southeastern Beaufort Sea during 1984. The reason for such a differential distribution remains unknown, although the principal investigator raised the concern that it may reflect an avoidance of the industrial zone by experienced older animals. On the other hand, this trend may be the result of differential feeing and/or habitat requirements of various size/age classes of the bowhead population since geographic segregation of bowheads and other baleen whales by size-class has been reported in other studies (e.g., Cubbage et al. 1984).

Three projects conducted in the past year examined the distribution of bowhead whales in relation to the locations of available food (areas containing high zooplankton densities), as inferred from easily measured environmental data (satellite imagery, observations of surface oceanograhic features and surface winds). If the findings of this line of research demonstrate that natural variability in environmental conditions account for the distribution of bowheads in the simultaneous presence of industrial activity, the validity of Hypothesis No. 1 would be greatly reduced. The three projects are: the satellite-imagery component of the 1984 Aerial Surveys, the Bowhead Feasibility Study, and G.A. Borstad's Remote Sensing Study (see Project Overviews 1, 2 and 33) in Appendix A.

All three studies provided evidence that relates bowhead whale distributions to natural environmental conditions. Borstad (1984) and Harwood and Borstad (1985) reported that the Herschel/Yukon coast and Cape Bathurst areas, often sites of large numbers of bowheads, commonly exhibit surface oceanographic features indicative of high levels of turbulence or upwelling activity. Several instances of coincidence of bowhead whales with thermal fronts, shear zones or surface convergences as indicated by ice strings, were documented in the two studies. While no *in situ* zooplankton data were available for these studies, zooplankton are commonly aggregated at these types of physical features elsewhere (Denman and Powell 1984). These findings suggest that the local aggregation of zooplankton by physical mechanisms may be important for feeding bowhead whales.

In the Bowhead Feasibility Study (Davis et al. 1985), analysis of a small amount of zooplankton data collected on the Tuktoyaktuk Shelf indicated that zooplankton abundance was positively correlated with salinity. This suggests that the low salinity water of the Mackenzie River plume may not be prime feeding habitats for bowhead whales. The highly variable wind-dependent area of the plume was mapped using satellite imagery and inferred prevailing winds for the period 1980-1983. The observed distributions of bowhead whales were then compared with the distributions of the plume. These comparisons indicated that the presence of whales in the industrial zone was associated with a northerly component to the wind and a resultant contraction of the low salinity plume. However, there were periods when whales were not present (particularly in 1982 and 1983), while wind and oceanographic conditions suggested that food may have been available.

In summary, the preliminary results of these three research projects suggest that the presence of bowhead whales in the industrial zone may be associated with the simultaneous presence of high salinity waters, and on some occasions, the presence of estuarine fronts. However, the reverse of these positive relationships may not be true. In general, the results of the studies investigating the relationship of bowhead distributions to oceanographic conditions have provided evidence in support of the hypothesis that natural environmental variability is important in determination of bowhead food availability. Similar relationships have also been clearly demonstrated for other baleen whales during studies conducted at lower latitudes (e.g., Nasu 1966). Moreover, studies in the Beaufort have identified possible techniques to determine areas that may contain high densities of zooplankton through more easily measured parameters (i.e., surface oceanographic features obtained from satellite imagery and prevailing winds). However, these measurement techniques required verification through concurrent measurements of zooplankton densities to assess and confirm their possible value as indicators of food availability.

Link 1: **Each active offshore island or platform will exclude bowheads from a zone around the island/platform.**

Link 2: **Ship traffic will exclude bowheads from a zone around the ship track.**

Link 3: **Each passage of a ship will reduce the feeding time available to bowheads.**

Link 4: **Eash passage of a ship will increase the energy expenditure of whales due to avoidance behaviour.**

Two projects conducted in 1984/85 have relevance to the above links:

OVERVIEW NO.	TITLE/INVESTIGATORS
37	Observations on the Behavior of the Bowhead Whale in Relation to Offshore Industrial Activity in the Beaufort Sea. Richardson 1985a.
38	The Behaviour of Bowhead Whales in the Presence of Operating Seismic Vessels. Ljungblad et al. 1985; Richardson 1985b.

During the past five years, the short-term behavioural reactions of summering bowhead whales to offshore industrial activities in the Canadian Beaufort Sea have been examined (Richardson 1985a). The two approaches used in this research have been (1) opportunistic observations of whales near oil industry operations, and (2) experiments designed to determine reactions of individuals to simulated industrial activities. Disturbance sources examined include aircraft, marine vessels, seismic operations and drillships.

Richardson (1985a) concluded that bowhead behaviour can be affected markedly by ships and aircraft, although changes in behaviour are only temporary and occur at relatively short distances from disturbance sources. Reactions of whales to more continuous noise sources (e.g., drilling, dredging, distant seismic operations) were less obvious. Bowheads appeared to behave normally when observed very near these sources of continuous industrial noise, with some tendency for animals to orient away from these sites at the onset of noise productions.

In 1984, two distinct studies of the short-term behavioural reactions of bowhead whales to seismic vessels were undertaken in the Alaskan Beaufort Sea (Ljungblad et al. 1985; Richardson 1985b). Experiments were conducted on both an opportunistic basis and under controlled conditions with a dedicated seismic ship. Detailed observations were recorded from circling aircraft. A series of tests were conducted using several seismic vessels in different geographic areas, and the observed behaviour of bowhead whales was generally consistent between the two studies and with previous investigations.

The general response of whales was to move away from an active, approaching seismic vessel. Noticeable and statistically verifiable responses were limited to bowheads within 6 or 7 km of the vessels. Experiments with an air gun and a full-scale seismic vessel showed that some bowheads moved when the noise source was very close. Ljungblad et al. (1985) found that bowhead whales exhibited changes in behaviour in response to the approach of active seismic vessels at distances ranging from 3.6 to 6.7 km, and Richardson (1985b) showed that bowhead activities were rarely altered in any noticeable manner when the distance to noise sources was greater than 6 km. This author also suggested that whales resumed pre-experiment behaviour within a short period (generally less than an hour) following termination of seismic operations.

Information potentially relevant to these links was also presented by a representative of the Alaskan North Slope Borough (C. George). Whaling captains from Barrow, Alaska are concerned that industry operations are causing the seaward displacement of bowheads during their fall migration past Barrow (Appendix A; Project Overview No. 34). However, the lack of any specific research related to this concern and the small amount of aerial survey data for the specific area limit use of the contribution in evaluation of Hypothesis No. 1.

Link 5: The available aquatic habitat determines the level of available food.

Link 6: The amount of available food and the time available for feeding determine the energy intake.

Link 7: Energy intake and expenditures determine the energy balance of a bowhead whale.

Recent studies that are relevant to the above linkages are listed below, with reference to their Appendix A Project Overview numbers.

OVERVIEW NO.	TITLE/INVESTIGATORS
34	Observations on the Digestive System of the Bowhead Whale. T. Albert and C. George. (Links 5, 6 and 7).
35	Primary Production in the Alaskan Beaufort Sea in Relation to Bowhead Whale Distribution. D. Schell. (Links 5 and 6).
36	Carbon Isotope Studies on Bowhead Whales. D. Schell. (Links 6 and 7).

Although the 1983-84 BEMP report recommendations were directed at the lower linkages (Links 1-4) of Hypothesis No. 1, some recent research projects conducted in Alaska are directly or indirectly relevant to the above links concerning the feeding and energy balance of bowhead whales.

Available data on the annual primary productivity in the Beaufort and Chukchi seas were presented by Schell as contours on maps of areas offshore of Alaska. Superposition of primary productivity contours on the locations of historical bowhead whale captures for the month of August during the period 1848-1919 results in a high degree of correlation between areas of production and harvest. This is consistent with the overall hypothesis that increased primary production will lead to higher rates of secondary production (reflected in greater zooplankton biomass), and that this secondary production may then support feeding bowheads.

Schell suggested that extension of existing primary productivity mapping into the eastern Beaufort Sea may be of value in the identification of prime bowhead whale feeding habitat. However, during review of the draft report, other members of the group expressed reservations on the usefulness of this exercise due to the time lag between phytoplankton and zooplankton production. As a result, areas of high primary and secondary production may not necessarily occur in the same region. It was suggested that a more direct approach would be to document zooplankton distribution rather than primary (phytoplankton) production.

During the workshop, Schell presented preliminary results on the carbon isotope content of muscle and oil samples which were obtained from a small number of bowheads harvested in Alaska. Whale tissue anaylses may provide information on the dependency of this population on specific habitats within its range, particularly if supporting data on carbon isotope content of prey organisms becomes available for various locations along its migration corridor. For example, the technique could help resolve the question of winter feeding.

Several stomachs were collected from bowheads taken in the Alaskan subsistence harvest, and have been examined as part of a study of the functional anatomy of the digestive tract. The stomach was found to be four-chambered and, therefore, similar in structure to stomachs of other cetaceans. The first chamber (forestomach) is non-glandular and possibly serves as a temporary food storage site. However, this forestomach is comparatively small in the bowhead. Based on limited observations, the first chamber does not appear to exceed 40 gal (150 L) in capacity, even in whales over 50 ft (16 m) in length. These findings suggest that the bowhead may not be capable of very large food intake, but rather must feed relatively continuously on small amounts of food. Although very few bowhead stomachs have been examined, the presence of food in some harvested whales also suggests that some feeding may occur during spring and fall migration.

CONCLUSIONS

The group concluded that Hypothesis No. 1 and its linkages remained valid. A new link (1a) was added to the hypothesis which states that: "The cumulative effect of all offshore industrial activities will be to create a large-scale zone of bowhead whale exclusion encompassing the entire industrial zone". This link underscores the approach and emphasis that was originally introduced during Phase I of BEMP, reflected during the 1984/85 bowhead research and monitoring programs, and further reinforced during the present workshop. On the other hand, less importance has been assigned to the evaluation of site-specific disturbances due to industry activities (Link 1), in part as a result of the recent studies of Richardson (1985a; 1985b) and Ljungblad et al. (1985).

In 1980, large numbers of bowhead whales occurred in the offshore industrial zone. A smaller proportion of the population has occupied this zone in the past four years (1981-1985). Two basic hypotheses have been advanced to explain these trends in bowhead whale distribution.

1) Bowhead whales are avoiding the zone of offshore hydrocarbon development due to the cumulative effects of industry facilities and activities.

2) The annual variability in bowhead distribution patterns is determined by a combination of physical and biological oceanographic factors, particularly those influencing large-scale differences in the distributions and abundance of zooplankton (the primary bowhead prey).

The group concluded that it was important to continue to document the annual patterns of whale distribution in the region, and to investigate the coincidence of bowhead whales with areas containing high densities of zooplankton, as well as more easily observable oceanographic and meteorological parameters.

RESEARCH AND MONITORING

During the 1985 BEMP workshop, continued emphasis was placed on the possible cumulative effects of industrial activities in terms of large-scale reductions in use of the industrial zone by bowhead whales. The workshop subgroup recommended that the priorities for research and monitoring in 1985 should be placed on (1) continuation of systematic surveys and studies of long-term behaviour through aerial photography of individual whales, and (2) studies of food distribution and availability (in relation to oceanographic phenomenon and bowhead distribution).

Other studies that were recommended in the previous BEMP report were believed to be less important in the near future, but may assume renewed importance depending on the results of the above programs. Specifically, these studies and the rationale for not pursuing them in 1985-86 are:

1. **Short-term Behavioural Responses** (Links 1, 2, 3, 4)

   The reasons for assigning a lower priority to this type of site-specific, short-term behavioural response research are: (1) the information that is now available, particulary the results of a 5-year study for the U.S. Minerals Management Service (Richardson et al.; various references), is sufficiently definitive to justify a shift in research emphasis, (2) the results of this research indicate that observable responses of bowheads to industry activities are minor, especially at distances of more than a few kilometres, and (3) the results of further research of this type would not provide data that are essential to address the question of overall exclusion of whales from the industrial zone.

2. **Energy Balance and Reproductive Rates** (Links 4, 7 and 8)

   Studies on the energy balance and reproductive rates of bowhead whales would only be of value in the testing of Hypothesis No. 1 if the lower links in this impact hypothesis are found to be both valid and likely. At present, such research is considered a low priority because the

validity of these lower links has not been established. The photogrammetic component of Research Recommendation B described below would, however, provide some information on reproductive rates of bowhead whales.

3. **Ambient Noise Monitoring** (Links 1, 1a and 2)

   This type of research is considered important to provide baseline data on existing ambient noise levels, particularly as a basis for comparison with noise levels in several years following an increase in the intensity of industrial development. However, little time during the workshop was devoted to discussion of ambient noise monitoring, and consensus on the immediate need for this type of research did not exist within the workshop subgroup. Some participants suggested that ambient noise measurements would not directly increase understanding of Links 1, 2 or 1(a) and, therefore, may not be essential at this time. During the preparation of this report, however, other individuals suggested that such monitoring would aid in delineation of the zones of influence of underwater noise from stationary and mobile industry operations relative to background conditions, and thereby provide some estimate of the size of the areas over which disturbance of bowheads is possible.

Two research programs were recommended and discussed in greater detail by the working group: (A) Food Availability Study, and (B) Integrated Systematic Surveys and Photography Program. The rationale for and general description of each recommended program is provided in the following sections.

RECOMMENDED PROGRAM A: FOOD AVAILABILITY STUDY

Program Rationale

The group recommended that an oceanographic study be conducted to determine densities of zooplankton in the region, and the relationships between zooplankton abundance/distribution and oceanographic and meteorological parameters. This recommendation was justified because further advances in the knowledge of the role of natural processes in determining the distribution of bowhead whales are required to assess the validity of Hypothesis No. 1. It appears possible that the decline in use of the industrial zone by bowhead whales since 1980 may be the result of natural variability in oceanographic conditions that influence the large-scale distribution and abundance of zooplankton. The significance and validity to Hypothesis No. 1 is largely dependent on the influence on variations in food availability within and outside of the industrial zone on the distributions of bowhead whales.

Program Objectives

The food availability study should be designed to: (1) obtain direct measurements of zooplankton abundance, and (2) simultaneously collect data on other oceanographic and meteorological parameters (e.g., temperature, salinity, chlorophyll concentrations and winds). A focus of the program should be to correlate readily obtainable information on meteorological and oceanographic phenomena (including oceanographic fronts) with large-scale zooplankton distribution in the region. The need for direct measurements of zooplankton abundance in the southeastern Beaufort Sea is apparent from the results of satellite imagery studies conducted by Borstad (1984) and Harwood and Borstad (1985), and the recent Bowhead Feasibility Study (Davis et al. 1985). In these research programs, conceptual models were developed which assumed that (1) zooplankton abundance was high in areas with observable surface oceanographic frontal features (Borstad 1984; Harwood and Borstad 1985) and (2) that abundance was related to large-scale patterns of surface temperature and salinity resulting from wind fields over the Tuktoyaktuk Continental Shelf region (Davis et al. 1985). If these conceptual models are valid, they should provide techniques for relating zooplankton abundance to more easily measured parameters (i.e., turbidity or temperature obtained from satellite imagery, or large -scale wind patterns).

Study Stategy

The group discussed a variety of approaches to the experimental design of this recommended research in terms of spatial and temporal measurement scales and sampling strategies. The sampling strategy must facilitate the collections of data at locations and times predicted to have both high and low zooplankton densities by the conceptual models being tested.

The emphasis, and indeed much of the effort, in the workshop was directed at designing a program that would adequately assess the comparative importance of natural variability in food availability with the effects of industrial activity. There was no concensus of the group as to the most appropriate study strategy.

During the workshop itself, considerable time was also spent on developing appropriate contingency tables as a strategy for testing the two hypotheses described earlier. Although the contingency table approach was useful in focusing the discussions of participants and was included in the draft version of the report, this material was removed during preparation of the final report. Such an approach was generally considered by reviewers of the draft to be an oversimplification and inadequate to address the complex questions implied by the impact hypothesis.

There were at least two viewpoints among participants as to the most appropriate strategy for the food availability study. The first approach, would focus research on the Tuktoyaktuk Continental Shelf, both within and outside of the zone of industrial development and would attempt to determine if patches of zooplankton at densities sufficiently high to support bowhead whales exist within the zone of industrial development. Completion of some research in areas off the shelf (e.g., along the Yukon coastline) was considered desirable only if the necessary sampling effort does not detract from the primary study objectives. This approach would involve testing of the model developed during the Bowhead Feasibility Study (i.e., zooplankton sampling on the shelf in areas both within and outside of the Mackenzie plume, where densities are predicted to differ very significantly.) If comparisons of the model results with directly measured zooplankton densities indicate high correlations, the model could then be applied to bowhead whale data from previous years. If these comparisons indicate that the model is invalid, the results from the Food Availability Study would still be of value, although limited to the period of sampling.

The second approach would not focus on any particular geographic area. Instead, it would study the relationship between the distribution of whales, the distributions of the food resource (zooplankton), and occurrences of identifiable oceanographic features. In this approach, the location of the Food Availability Study would be largely determined by the distribution or concentration of whales. Further steps in this progression would then be used to evaluate the relationship between whales, zooplankton and the industrial zone, with a final determination (if necessary) as to whether or not removal of industrial zone would in fact be critical to the status of the whale population.

Experimental Methods

Unlike surface water temperature, turbidity and relative chlorophyll content, zooplankton abundance cannot easily be determined remotely from aircraft or satellites. As a result, most participants felt that the Food Availability Study will require surveys from a suitably-fitted oceanographic vessel, with associated limitations of low speed spatial sampling, and relatively high costs. It is likely that the most practical approach for determination of the abundance of larger zooplankton, which can readily avoid conventional plankton nets, will be the use of high-frequency hydroacoustic devices. However, these instruments are still being refined, and therefore, will have to be carefully evaluated during the initial phase of this research. It will also be necessary to calibrate any hydroacoustic techniques against more conventional sampling gear (e.g., low avoidance nets). Studies underway in other nations, such as the international "BIOMASS" program for southern ocean krill stocks, should be evaluated during the selection of most appropriate sampling techniques for the Food Availability Study.

The actual sampling strategy should involve the establishment of survey grids. To the extent allowed by financial resources and logistical considerations, these grids should be stratified to provide both broad regional coverage and detailed examination of individual oceanographic features (e.g., fronts). Such grids, however, should not be rigidly fixed. Due to limited existing information concerning the size and persistence (or recurrence) of discrete zooplankton patches in the eastern Beaufort Sea, the sampling program will also have to be flexible and data-adaptive. For example, real-time information must be processed aboard the ship to allow sampling stategies to be modified as the study proceeds. In addition, oceanographic remote sensing from satellites and bowhead whale distribution data should be synoptic in the vicinity of the survey ship and should be provided to the scientific team aboard the vessel on a real-time basis to allow the planning of subsequent sampling programs.

Essential data and ancillary information that should be collected from the research vessel include:

A. Essential Data

1. Zooplankton densities (by hydroacoustics). These data should resolve patch scale and orientation as well as the bulk population density;
2. Independent zooplankton biomass and species composition data from frequent net tows to facilitate calibration of the hydroacoustic instrumentation;
3. Continuous determination of surface temperature, salinity and chlorophyll concentrations;
4. Subsurface oceanography (XBT, CTD);
5. Accurate positioning data for all samples and measurements; and
6. Meteorlogical data and sea state.

B. Desirable Data:

1. Characterization of local whale density and activity; and
2. "Snapshots" (by satellite or air) of surface oceanographic pattern and its time derivative.

The estimated time required to adequately conduct this research program would be one month or more of ship time. A second season of oceanographic surveys may be required to fully address the question of bowhead food availability within and outside the industrial zone, but this would have to be justified on the basis of the results of the first season of research and re-evaluation of information requirements related to BEMP Hypothesis No. 1.

RECOMMENDED PROGRAM B: INTEGRATED SYSTEMATIC SURVEY AND PHOTOGRAPHY PROGRAM

Program Rationale and Objectives

The group concluded that the annual systematic aerial surveys of bowhead whales should be continued. The photographic study of bowhead whales was also viewed as a worthwhile approach by the group, and should be closely linked to the systematic surveys. The studies could be conducted as two separate programs or merged into a single integrated research program. The latter was recommended because it would allow more closely co-ordinated surveys and comparable biological data. Information resulting from the aerial photography component could also permit the evaluation of correction factors and allowing some analysis of the inter-day movement patterns of bowhead whales.

Continuation of studies to document the patterns of bowhead use of the southeastern Beaufort Sea in general, and the industrial zone in particular, are important to provide the data that will eventually allow testing of the impact hypothesis. These data are also necessary simply to document whether trends in the distribution of bowheads observed since 1980 continue. Continuation of systematic aerial surveys would provide information on the general distribution of whales in the region for a sixth year in

this time-series. However, there are limitations to systematic surveys because they do not provide data on whale movements or the residence times of groups of whales. In addition, these surveys cannot provide information on the differential distribution of the various age classes of the population. The results of the 1984 photogrammetry studies suggest that the situation is more complicated than indicated by systematic survey results. Most of the whales within or near the industrial zone in 1984 were small animals, probably yearlings. Very few large animals (adults and near-adults) were present in this zone. The reason for this differential distribution is unknown. It is important to document whether the older bowheads occupy the industrial area in future, or if use of this zone is restricted to yearlings.

It will also be important to determine the activities of bowheads within the study area. As a result, this research should document residence times in particular areas by groups of whales and movement patterns within the area. This information can be provided by the photogrammetric component of the recommended research program.

Experimental Design

The workshop participants recommended that the synoptic approach of systematic aerial surveys be combined with the more detailed and biologically informative aspects of aerial photography (including length frequency data, calf/adult ratios, etc.). The basic design of an integrated program should combine the photogrammetric investigations with systematic searches using a transect survey method to provide the necessary geographic coverage.

There was no agreement at the workshop itself concerning certain aspects of the experimental design of this research. However, it was agreed that selected areas and groups of whales identified during the systematic phase of the surveys should be re-visited and whales re-photographed to provide information on the residence time of identifiable animals. The re-photography of individual whales at different times during the study would also provide some information on movement patterns (particularly adults and near-adults). Specific oceanographic features such as fronts and other discontinuities should also be examined in greater detail than in past programs.

The recommended study combining systematic survey and photogrammetric components will provide useful data for relating patterns of whale distribution and habitat use to the results of the Food Availability Study. It would be desirable to have close co-ordination between the two programs, recognizing that there will be some limit to the cooperation that would be possible without jeopardizing the objectives of the aerial program. The repeated surveys and re-photography referred to above could be designed to examine whales in areas determined to be of interest to the oceanographers involved in the Food Availability Study.

The group also discussed the feasibility and potential benefits of a radiotagging or satellite monitoring program. It was stated that the U.S. Minerals Management Service is continuing to support a research and development program for tagging and satellite monitoring of bowheads and other large baleen whales. The actual physical application of tags to bowhead whales is not anticipated until at least 1986. Although some reservations with respect to tagging were expressed, the progress of the U.S. program was considered of interest in relation to the BEMP hypothesis.

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HYPOTHESIS NO. 2

VARIOUS FACILITIES AND ACTIVITIES ASSOCIATED WITH OFFSHORE HYDROCARBON DEVELOPMENT WILL AFFECT THE WHITE WHALE HARVEST

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INTRODUCTION

The working group agreed with the existing statements of each sub-hypothesis and the overall structure of their associated linkages as illustrated in Figure 2-1. However, after reviewing the information relevant to each linkage, Links 3 and 4 were reworded and de-emphasized. The revised statements of these links are shown in Figure 2-1. New information pertinent to each linkage and recommendations for research and monitoring are described in the following sections.

REVIEW OF LINKAGES AND RELEVANT RESEARCH

Link 1: Artifical islands off the Mackenzie Delta will delay the regional break-up of the landfast ice.

An ongoing program to obtain data on ice conditions in the Beaufort Sea is sponsored by the petroleum industry. Daily synthetic aperture radar (SAR) overflights are conducted from June 14 through July 31. Data obtained during these flights could be used to assess break-up chronology, although break-up patterns are presently monitored using satellite imagery. The latter program suggested that artificial islands in the Mackenzie Delta did not delay regional break-up during the 1984 season.

Existing information suggests that artificial islands spaced at 10 or 15 km intervals do not increase the amount of anchoring of the landfast ice sheet, although the group concluded that Link 1 remains valid for larger numbers and closer spacing of offshore structures. The present monitoring system allows detection of time of break-up, but does not provide any evidence of the causal factors. Documentation of the factors that affect the timing and pattern of ice break-up would require a large-scale study on ice mechanics. Since mitigative measures (i.e., use of icebreakers) are presently available if ice break-up is unusually late, it was concluded that this research program is unnecessary at present levels of development in the region.

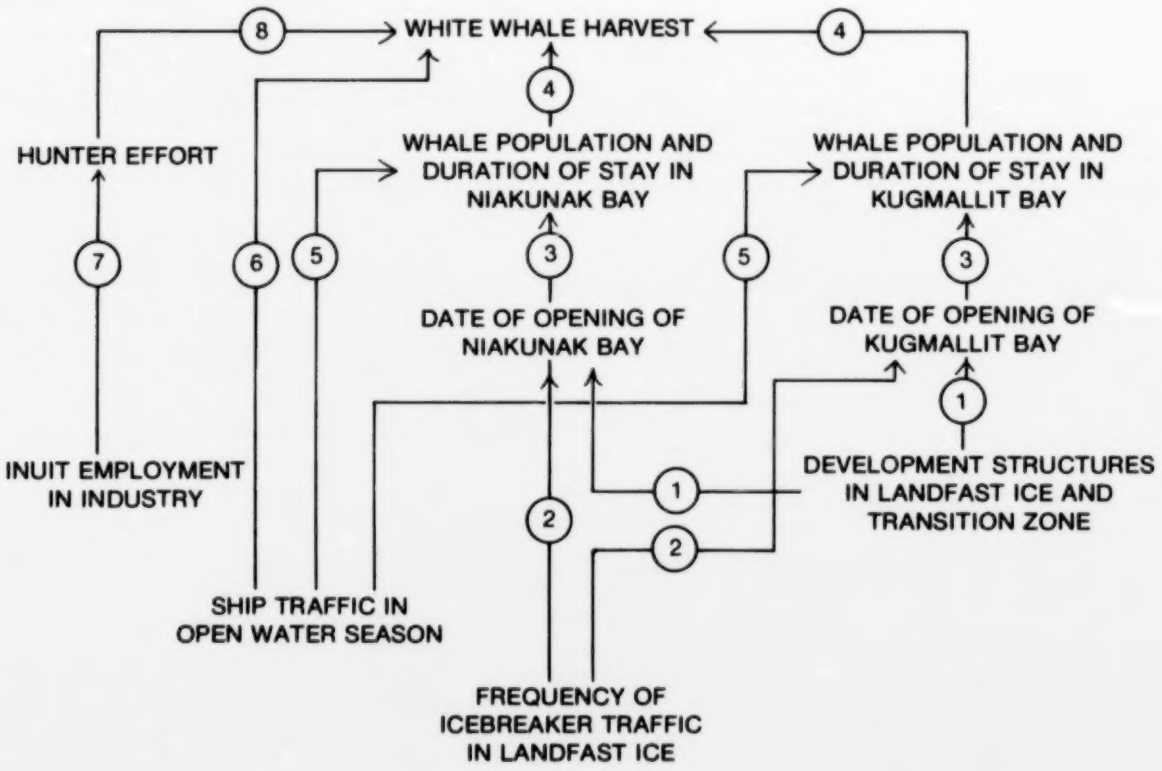
FIGURE 2-1

THE EFFECTS OF VARIOUS FACILITIES AND ACTIVITIES ASSOCIATED WITH OFFSHORE HYDROCARBON DEVELOPMENT ON THE WHITE WHALE HARVEST

A. Offshore structures will reduce the white whale harvest.

B. Frequent icebreaker traffic in landfast ice will increase the white whale harvest.

C. Open water ship traffic in the Mackenzie Estuary will alter white whale distribution and lead to changes in harvest levels.



Linkages

1. Artificial islands off the Mackenzie Delta will delay the regional break-up of landfast ice.
2. Icebreaker traffic in the landfast ice in spring will advance the break-up of ice barriers across Kugmallit and Niakunak bays.
3. The timing of break-up of the landfast ice influences the timing of entry, and the numbers and the duration of residence of white whales in Niakunak and Kugmallit bays.
4. The numbers and the duration of residence of white whales in Kugmallit and Niakunak bays will influence the white whale harvest.
5. Ship passages through Niakunak and Kugmallit bays will disturb white whales, and this will reduce the number of animals that frequent the bays and/or the time that whales spend in the bays.
6. Ship traffic in Niakunak and Kugmallit bays will lead to changes in the distribution of whales in the bays, and these changes will lead to changes (probably reductions) in the harvest levels. In addition, ship traffic could directly interfere with hunting activities by frightening whales that are being hunted.
7. Increased Inuit employment by the oil industry and various supporting businesses will lead to changes in hunter effort.
8. Changes in hunter effort and experience will lead to changes in white whale harvest.

Link 2: Icebreaker traffic in the landfast ice in spring will advance the break-up of ice barriers across Kugmallit and Niakunak bays.

There have been no studies during the past year that specifically provide information directly applicable to Link 2. Information that may be partially relevant was provided during the 1983 whale behaviour study in the eastern Arctic (Finley and Davis 1984; see Links 5 and 6 for further description of this study). A crack formed in the fast ice in Lancaster Sound as an icebreaker was progressing through the sheet. The crack formed at an angle to the icebreaker track and may have advanced break-up. However, participants questioned the applicability of this evidence to Kugmallit and Niakunak bays where ice sheets are grounded.

It was concluded that Link 2 is valid, but that research related to this linkage is not necessary because current industry plans do not include icebreaker traffic through Kugmallit and Niakunak bays. If icebreakers did operate in these areas and advanced the timing of break-up, this may advance the start of the white whale hunt, but is unlikely to cause a large change in the number of whales landed.

Link 3: The timing of break-up of the landfast ice influences the timing of entry, and the numbers and the duration of residence of white whales in Niakunak and Kugmallit bays.

Previous studies have shown that white whales first enter Niakunak Bay a few hours to 13 days after break-up first allows access (Fraker 1977b; Fraker and Fraker 1981). The range in the time between break-up and whale entry indicates that factors other than timing of break-up affect the timing of whale entry into the Mackenzie Estuary. Endogenous factors such as biological rhythms may dictate or strongly influence the timing of white whale movement, or exogenous factors such as ice conditions in Amundsen Gulf or along their migration corridor may affect the timing of movement into the estuary. There is no doubt that if break-up is delayed until the middle of July, this would be the factor determining the time of entry. However, since timing of break-up is not the only factor affecting timing of entry, the group recommended that the wording of Link 3 be changed from "determines" to "influences".

Changes in the timing of break-up in Niakunak Bay relative to Kugmallit Bay can influence the relative abundance and distribution of whales within the estuary. On the average, Niakunak Bay is accessible to white whales three days before Kugmallit Bay (Robertson and Millar 1984). If the migration to the estuary peaks before Kugmallit Bay is open, most of the animals go to Niakunak Bay. If break-up is very late (i.e., mid July), then the duration of white whale residence in the estuary will be shorter. Studies conducted in the eastern Arctic suggest that white whales occupy alternate estuaries if traditionally used areas are not accessible (Finley 1976).

Patterns of white whale distribution within nearshore and offshore areas of the Beaufort Sea were examined during a 1984 study funded by DFO (Freshwater Institute). One-third of the white whales estimated to be in the Beaufort Sea during early July were in offshore areas; the remaining two-thirds were estimated to be in the Mackenzie Estuary (Norton and Harwood 1985). This observation of relatively large numbers of white whales in offshore areas during the period of estuarine occupation suggests that either: (1) white whale groups move back and forth between offshore and estuarine areas; or (2) groups enter the estuary, stay a short time before moving offshore and are replaced by new groups. Data collected at the Mucalic River in northern Quebec by Finley et al. (1982) suggest that the same animals used that estuary during the study period. A tagging study would be necessary to differentiate which of the suggested movement patterns predominate in the Beaufort Sea. There was discussion of potential tagging methods, although the subgroup did not recommend that a tagging study be initiated in the Beaufort at this time. It was noted, however, that a study of tagging/marking methods for white whales is presently under way near Churchill, Manitoba (Seal River). The program is jointly funded by the World Wildlife Fund (Canada) and DFO, and field work will be complete in 1985. Nevertheless, even in the absence of information regarding movements, the persistent use of estuarine areas by white whales indicates that these habitats are important to the species.

Studies evaluating census techniques have broad relevance to Link 3 and to any other linkages which involve specifying of the number of whales (i.e., Links 4 and 5). Two ongoing studies of census techniques are being conducted from the Freshwater Institute (DFO). The results of one research program in the eastern Arctic suggest that underwater vocalizations are a good indicator of the presence/absence or relative numbers (but not absolute numbers) of white whales or narwhal. However, it is expected that sound attenuates rapidly in the shallow Mackenzie Estuary, and therefore the usefulness of this technique for censusing of white whales in Niakunak and Kugmallit bays is questionable.

Remote sensing using a 9"-format camera, a second forward-looking camera with infra-red film and a low light TV camera has been tested on marine mammals in the eastern Arctic, and was found to be a better technique for estimating numbers than the visual surveying procedures. Additional parameters that cannot be reliably discerned by direct observation (e.g., relative size, group composition) can be determined from the photographs and random recounts of photographs can provide a measure of the technique's precision. However, remote sensing is more expensive to use and requires better light and weather conditions (i.e., minimum ceiling of 915 m) than the visual surveying technique. Remote sensing is also most effective in areas where whales concentrate. The flight altitude selected for remote sensing surveys largely depends on the purpose of the surveys. In some cases, altitudes greater than 915 m may be appropriate because this increases the "swath width" (photo coverage) and results in greater cost-effectiveness. DFO plans to test the remote sensing technique in the Beaufort Sea during the 1985 field season.

The group concluded that Link 3 is valid as reworded, but recommended that the emphasis on this link be reduced.

Link 4: The numbers and the duration of residence of white whales in Kugmallit and Niakunak bays will influence the white whale harvest.

The Freshwater Institute (DFO) has monitored the white whale harvest in the Mackenzie Estuary for the last four years. The results of this program will be published in 1985. During this period there have been no significant year-to-year changes in the number of landed whales. (Hunting techniques, percent females landed and number of whales struck-and-lost have varied, but these aspects of the harvest are more relevant to other linkages.)

Participants agreed that timing of entry would influence the number of harvested whales only through its effect on whale numbers and duration of residence. Number of hunting days with good weather, number of hunters and level of hunting effort have a greater influence on the harvest level than the timing of white whale entry to the estuary. The group therefore recommended that "Timing of entry" be removed from the statement of Link 4.

Of indirect relevance to Link 4 and any other linkages involving harvest level (i.e., Links 6 and 8) is an ESRF study evaluating the reliability of harvest data collected by different methods. However, specific information from this study was not available for review at the present workshop.

Link 4 was expected to remain valid, but would only be important when long periods of adverse weather coincide with the period when white whales occupy the estuary.

Link 5: Ship passages through Niakunak and Kugmallit bays will disturb white whales and this will reduce the number of animals that frequent the bays and/or the time that whales spend in the bays.

Link 6: Ship traffic in Niakunak and Kugmallit bays will lead to changes in the distribution of whales in the bays, and these changes will lead to changes (probably reductions) in the harvest levels. In addition, ship traffic could directly interfere with hunting activities by frightening whales that are being hunted.

An ongoing camp liaison program supported by the oil industry has been successfully monitoring possible interference of ship traffic with the white whale harvest for several years. During that time, industry activities have gradually been moving further offshore, and no conflicts between hunting and ship traffic have been reported in the past two years.

Data from programs conducted in previous years included observations of short-term reactions of white whales to ship traffic. For example, Fraker (1977a) reported that white whales within 2.4 km of moving barges swam away from the vessels' track. The results of an acoustics study conducted in a different area of the estuary suggested that one of the barges should have been audible to whales when 3.3. km away (Ford 1977). The area around the vessels' track was surveyed twice after the barge move was completed, and whale distribution returned to the pre-disturbance pattern between three and 30 hours after the barges had passed (Fraker 1977a).

Previous white whale monitoring programs have also provided information on the possible level of ship traffic that results in longer-lasting (measured in days) changes. White whales were observed in an arm of Hutchison Bay just to the northeast of a vessel route for 14 days when barge traffic was at a level of 25 passes/day (Fraker 1977b). Whales were reported to move southwest toward the barge route and then veer north when a barge approached. The number of whales remaining in the area was the same until shortly after barge traffic was stopped for two days. Traffic levels then decreased to less than 20 passes/day and no subsequent concentrations of whales were recorded in the area.

In contrast to the situation in the Beaufort Sea, reactions of white whales to icebreaker traffic have been documented in the eastern Arctic. White whales were found to be very sensitive to ship traffic; animals reacted to the icebreaker MV ARCTIC when it was up to 80 km away in open water and left the ice edge (where they had concentrated) for shallow water areas when the icebreaker was within 40 km (Finley and Davis 1984). The whales slowly returned to their pre-disturbance distribution pattern after passage of the MV ARCTIC into the ice sheet. White whales also exhibited startled responses when the engines of a stationary icebreaker were started. However, these whales moved toward the operating icebreaker when a crack that formed in the ice sheet allowed their continued movement westward in the direction of their destination.

This experiment in the eastern Arctic involved a Lancaster Sound population that was waiting along the ice edge in an area where sound propogates well. The applicability of these observations is not known for white whales in an estuary, where sound attenuates more rapidly or where industrial or shipping noise has been common for a number of years. A similar but less intense reaction to ship noise was observed in white whales waiting outside of the ice barrier across Kugmallit Bay in 1981 (Norton Fraker and Fraker 1982). Whales moved toward the ice edge when the engines of a stationary supply boat, approximately 3 km away, were started and the vessel moved. However, the whales that had suddenly altered course passed within 100 m of a supply boat located in an indentation on the ice sheet. It was suggested that the observed differences in the reactions of white whales to ship traffic may be related to differences in the motivation which causes whales to be in a particular place at a given time.

Based on the information presented at the workshop, the group questioned the validity of Link 5 for the present levels of ship traffic in the region, but did not recommend deletion of this link from Hypothesis No. 2 in the event that more intense shipping activity occurs in the future. Ship traffic could disrupt the migration of white whales to the estuary, but this was also considered unlikely at present traffic levels. Link 6 was expected to remain valid, although existing monitoring and liaison programs minimize potential concerns related to changes in white whale harvest levels.

Link 7: Increased Inuit employment by the oil industry and various supporting businesses will lead to changes in hunter effort.

Hunters at the whaling camps have suggested to scientists from the Freshwater Institute (DFO) that wage employment of Inuit by the oil industry has resulted in the participation of less experienced hunters in the harvest. Most of these new hunters are using Tuktoyaktuk as a base, and the same hunters tend to use the whaling camps each year. Some of these hunters are employed by the oil industry, but work schedules of these individuals are generally arranged to allow their participation in the annual harvest.

A study by the Institute of Socio-economic Research at the University of Alaska (Kruse 1982) indicated that employment of Alaskan Inuit by the oil industry resulted in little decrease in the time spent or interest in traditional activities throughout the year. However, several participants in the working group suggested that wage employment would lead to fewer hunters conducting a greater proportion of the harvest. Therefore, the group concluded that Link 7 remained valid. (Editor's Note: changes in resource harvest patterns and intensity resulting from employment of Inuit by the oil industry are being evaluated in greater detail as part of the Mackenzie Environmental Monitoring Project).

Link 8: Changes in hunter effort and experience will lead to changes in the white whale harvest.

Although no recent studies have directly addressed Link 8 in this hypothesis, several participants not present at previous BEMP workshops provided information that supplemented the description of this link in the 1983-84 BEMP report.

Local Hunters and Trappers Associations and DFO are concerned that the number of white whales removed from the population during the annual harvest may increase due to a larger proportion of animals that are struck-and-lost. This increase in number of whales struck-and-lost is attributed to less experienced hunters participating in the harvest. A similar situation has been documented with the bowhead harvest in Alaska. In the Mackenzie Delta, a high struck-and-lost ratio in 1981 coincided with the participation of inexperienced hunters from elsewhere in the Beaufort region in the white whale hunt. The group therefore concluded that Link 8 remained valid.

CONCLUSIONS

The workshop group confirmed the validity of Hypothesis No. 2, but concluded that less emphasis should be placed on several of its linkages. Delayed ice break-up due to presence of artificial islands is possible although considered unlikely given the distance between the number of existing islands. Icebreaker traffic could advance break-up, but this is not anticipated given the present development scenario. A negative correlation between arrival date and size of the harvest was expected to be valid only because arrival date can affect the number of white whales in the estuary and the duration of their residence. Present levels of ship traffic are unlikely to prevent white whales from entering the Mackenzie Estuary, although ship traffic may cause local and short-term changes in distribution. Wage employment of hunters in the petroleum industry may change the pattern of hunting, but participants did not expect this to cause any substantial changes in the size of the harvest.

RESEARCH AND MONITORING

The importance of understanding natural factors that influence white whale distribution within the Mackenzie Estuary was discussed by the group. It was agreed that this is a major data gap in present knowledge of white whale biology, although research to address these data deficiencies was not recommended for two reasons. Firstly, there is an adequate data base on normal white whale distribution patterns within the estuary to allow detection of any large deviations in distributions that may be associated with industry activities. Secondly, industry is already committed to the mitigation of any perceived concerns related to the effects of their operations on the white whale harvest, regardless of the cause of any changes.

No expansion of the existing white whale monitoring programs are recommended unless the level of industry activity increases within the Mackenzie Estuary. In addition, frequency of aerial surveys could be decreased to once every two or three years rather than every year given the present data base regarding use of the Mackenzie Estuary by white whales. However, monitoring of break-up, harvest levels and possible interference by industry activities with the white whale hunt should be continued at previous levels.

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HYPOTHESIS NO. 3

MARINE VESSEL ACTIVITIES, SEISMIC OPERATIONS, DREDGING OPERATIONS, AIRCRAFT OVERFLIGHTS AND ACTIVE OFFSHORE PLATFORMS/ARTIFICIAL ISLANDS WILL REDUCE THE SIZE OF RINGED AND BEARDED SEAL POPULATIONS IN THE BEAUFORT SEA

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INTRODUCTION

The workshop subgroup agreed with the statement of this hypothesis and its associated linkages provided in the 1983-84 BEMP report (Figure 3-1). The hypothesis focuses on the cumulative effects of vessel, seismic, dredging, aircraft and platform activities on the energy balance of ringed and bearded seals through (1) reductions in the amount of time available for feeding and/or (2) increased energy costs due to avoidance behaviour. A negative energy balance could then lead to reduced reproductive rates in ringed and bearded seal populations.

Following a link-by-link review of the hypothesis, Links 5 and 6 were reworded as indicated in Figure 3-1 and discussed later. Two ongoing research projects were directly related to specific links of the hypothesis and discussed in detail, while a third study of indirect relevance to Links 1 and 9 was initiated since the last BEMP workshop and also evaluated.

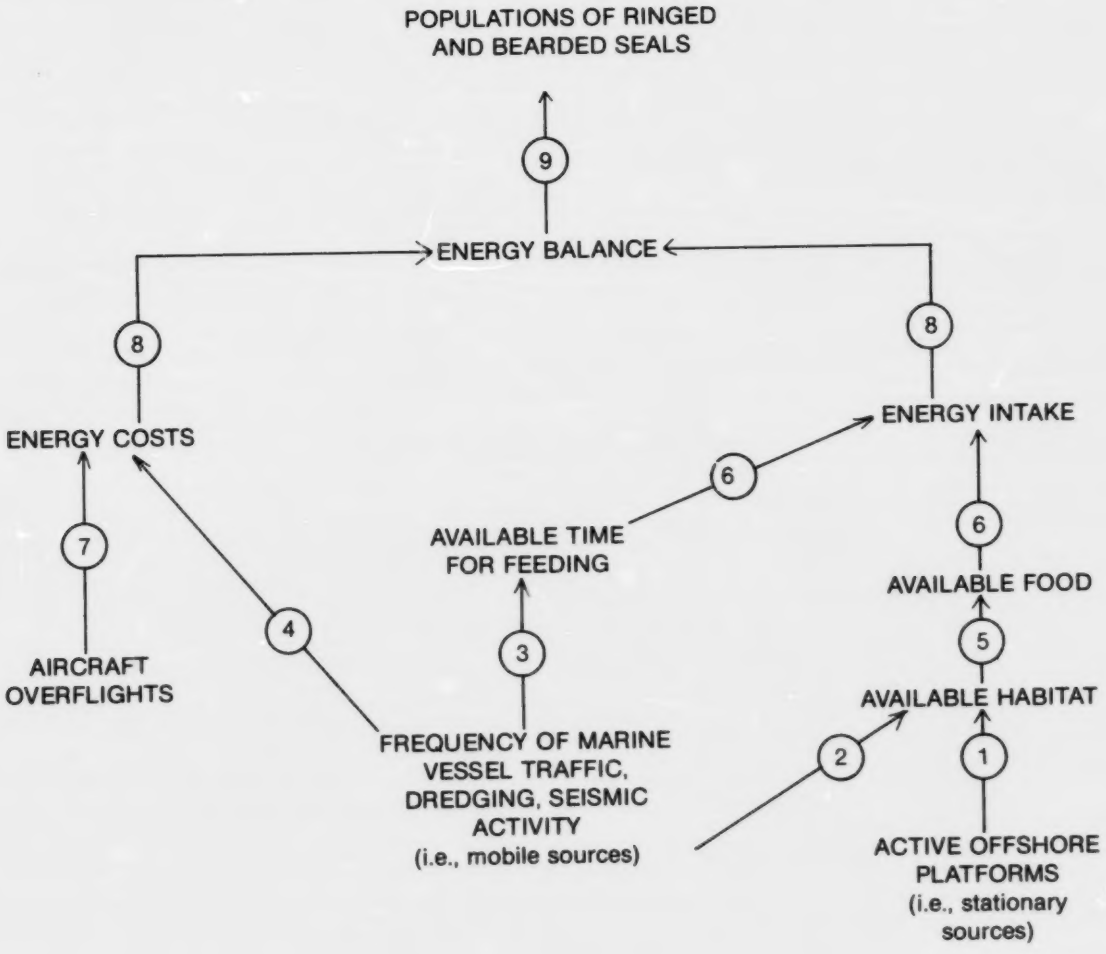
During the initial discussion of Hypothesis No. 3, two errors were noted in the version of Figure 3-1 in the 1983-84 BEMP report; these were corrected for the present flowchart. At this time, one participant suggested that chronic oil spills be added to the list of environmental pertubations considered in Hypothesis No. 3, although this was not pursued further during the workshop. The Chairman of the BEMP Management Committee believes that chronic oil spills should not be considered within the framework of this hypothesis because the existing linkages focus on the energetics of individual seals and seal populations, while the majority of the documented effects of petroleum hydrocarbons on seals are related to physical contact with oil (e.g., eye irritations). If chronic oil spill-seal interactions are a valid concern of the working group, this should be the subject of a new hypothesis formulated during a subsequent BEMP workshop or technical meeting.

Participants in the previous BEMP workshop concluded that this hypothesis was valid, but the cumulative effects of all links would probably be inconsequential, or be too hard to detect. Although the present subgroup agreed with this conclusion, it was considered important to review the results of recent and ongoing investigations relevant to Hypothesis No. 3.

FIGURE 3-1

THE EFFECTS OF VARIOUS OFFSHORE ACTIVITIES AND FACILITIES ON POPULATIONS OF RINGED AND BEARDED SEALS IN THE BEAUFORT SEA

Marine vessel traffic, seismic activities, dredging operations aircraft overflights and active offshore platforms/islands will reduce the size of populations of ringed and bearded seals in the Beaufort sea



Linkages

1. Each active offshore platform will result in the exclusion of ringed and bearded seals from some habitat.
2. Marine traffic (ships, dredges, seismic vessels) will exclude ringed and bearded seals from available habitat.
3. Each passage of a ship or other marine vessel will reduce the feeding time available to ringed and bearded seals.
4. Each passage of a vessel will increase the energy expenditure of seals because of avoidance behaviour.
5. The available aquatic habitat can influence the level of available food.
6. The amount and quality of available food and the time available for feeding determine energy intake.
7. Noise from aircraft overflights will disturb hauled-out seals and lead to increased energy costs.
8. Energy intake and costs determine energy balance.
9. The energy balance of a seal determines its survival and its ability to reproduce. The energy balance of the individuals in a population influences the reproductive capacity and health of the population.

REVIEW OF LINKAGES AND RELEVANT RESEARCH

Link 1: Each active offshore platform will result in the exclusion of ringed and bearded seals from some habitat.

In 1984, the Freshwater Institute (DFO) concluded the fourth and final year of a survey series which is directly applicable to this link. The purpose of the study was to monitor the abundance and distribution of hauled-out ringed seals relative to oil and gas industry activities in the Beaufort Sea, to determine if these activities are having detectable effects on seals.

As in 1981-1983, no correlation between low densities of hauled-out seals and proximity to industrial activity was found during the 1984 monitoring program. Data collected during all four years of the program will be analysed to determine if the installation, operation and removal of industry structures in the offshore has affected densities of hauled-out seals.

While the present working participants concluded that Link 1 was valid, the extent of exclusion was expected to be inconsequential and limited to the physical extent of offshore islands and structures.

Link 2: Marine traffic (ships, dredges, seismic vessels) will exclude ringed and bearded seals from available habitat.

Link 3: Each passage of a ship or other marine vessel will reduce the feeding time available to ringed and bearded seals.

No new information was available to re-evaluate these links. The group agreed that the links remained valid, but anticipated that effects would be insignificant at both the individual and population levels.

Subgroup participants requested information concerning the results of a study designed to examine the effects of seismic operations in Alaskan waters on seal distribution. The preliminary results of this monitoring program suggested that winter on-ice seismic activities resulted in extremely localized habitat exclusion, and were unlikely to affect seal populations (Burns and Kelly 1982). This program was also discussed during the last BEMP workshop.

Link 5: The available aquatic habitat can influence the level of available food.

This link was reworded (i.e., "influence" from "determine") to reflect the patch distribution of seal prey organisms, since it was noted that prey distribution is not homogeneous throughout the southeastern Beaufort Sea.

Link 6: The amount and quality of available food and the time available for feeding determine energy intake.

While this link was considered valid as in the previous BEMP workshop, it was expected that time available for feeding may only be a limiting factor during the fall-early winter feeding period. The body condition of seals in the fall appears to affect reproductive success during the following spring through its effect on ovulation rates (see Link 9). In addition, seal distribution within and among preferred breeding areas appears to be related to body condition.

The subgroup recommended that this link be expanded and reworded to include food quality (e.g., lipid content) as well as availability.

Link 8: Energy intake and costs determine energy balance. This link is self-evident and valid.

Link 4: Each passage of a vessel will increase the energy expenditure of seals because of avoidance behaviour.

Link 7: Noise from aircraft overflights will disturb hauled-out seals and lead to increased energy costs.

These links suggest that increased energy costs to seals will result from avoidance of vessels (Link 4) and diving in response to aircraft overflights (Link 7). No new information was available to evaluate Link 4, although several recent observations of seal diving behaviour in the presence of aircraft were described by subgroup participants. In the Beaufort region, seals hauled-out during early July did not dive when overflown by a Twin Otter aircraft at an altitude of 305 m. On the other hand, seals in Barrow Strait overflown by a helicopter at altitudes of 100-150 m frequently dove, often eliciting a perceived panic response. Another recipient noted that seals regularly frequent waters at the end of Resolute Bay airstrip.

Given the amount of aerial survey effort in the Beaufort region each year and the resultant opportunities for documenting seal behaviour in the presence of aircraft, it was suggested that observers involved in survey programs routinely record the frequency of diving responses in seals.

The opportunistic recording of diving responses would not provide information on the potential for seals to vacate an area, and the amount of aircraft activity and flight altitudes that could result in such a response. The 1983-84 BEMP report described a study by Finley (1976) which indirectly examined the possibility that seals would vacate an area repeatedly overflown in Resolute Passage. However, no evidence was found to suggest that ringed seals had vacated the area. In the present workshop, T. Smith (DFO) indicated that seal distributions near Baffin Island returned to normal following a few opportunistic overflights.

The workshop subgroup expected that both of these hypothesis links remained valid. However, it was concluded that energetic costs associated with avoidance and diving responses would probably be insignificant from a regional perspective.

Link 9: The energy balance of a seal determines its survival and its ability to reproduce. The energy balance of the individuals in a population influences the reproductive capacity and health of the population.

This link was considered self-evident and completely valid. Various aspects of the population structure, recruitment, annual movements and physiological condition of ringed seals have been examined in the Amundsen Gulf region over the period from 1971 to 1981 (T. Smith, Arctic Biological Station). Publication of the results of this research is anticipated in fall 1985. The study indicates a high correlation between ringed seal body condition and reproductive success. Females with reduced body condition were noted in 1974 and 1975, and showed a marked reduction in ovulation rate. Reproductive rates returned to pre-1974 levels in 1976, and stayed at that level for the remaining years examined. The effect of body condition on reproductive success was not age-specific among females of breeding age. No obvious relationship between reduced ovulation rate and ice conditions was detected, and it was speculated that the effect may have been related to reduced food availability and/or food quality.

A study to review remote sensing systems, and to recommend and specify an optimal system for remote sensing of arctic marine mammals was initiated by the Freshwater Institute (DFO) in 1984. The techniques being tested during this program are described in the discussion of Link 3 of Hypothesis No. 2. Future work on remote sensing systems will be relevant to this link, as well as others (e.g., Link 1) that involve estimation of seal abundance. The research completed to date has focused on ondontocete whales in the eastern Arctic, although work planned for 1985 includes remote censusing of seals in Amundsen Gulf.

CONCLUSIONS

As in the 1983-84 BEMP report, the group concluded that all links in Hypothesis No. 3 were valid. However, it was agreed that the cumulative effects of the developmental activities considered in this hypothesis, at the present level of industry activity, would be inconsequential to Beaufort Sea ringed and bearded seal populations. Population-wide effects would either be unlikely or too hard to detect because of the natural variability in seal population levels in this region.

RESEARCH AND MONITORING

As in the previous BEMP workshop, no specific research or monitoring programs were recommended by the participants to address this hypothesis.

The potential use of the body condition index and ovulation rate as a future monitoring tool was discussed, since altered energy condition of seals affects fecundity. Seal length and girth data collected in the Beaufort Sea by CWS during 1974-77 may be useful for examining past seal condition in this region, particularly if samples are collected during the future. It was also emphasized that mortality/survivorship was not a suitable means of monitoring effects on the population because these measurements are not sufficiently sensitive and have numerous associated biases. However, the group also noted that ovulation rate may not be a useful monitoring tool in relation to the BEMP hypothesis because it is affected by sudden and widespread changes (e.g., food availability), and therefore may not be a suitable indicator of low level chronic/cumulative effects of industrial development on seal populations.

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HYPOTHESIS NO. 4

INCREASED FREQUENCY OF ICEBREAKER TRAFFIC THROUGH THE LANDFAST ICE AND THROUGH AMUNDSEN GULF WILL REDUCE RINGED SEAL PUP PRODUCTION AND HAVE SUBSEQUENT EFFECTS ON POPULATION LEVELS

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INTRODUCTION

After reviewing this hypothesis and its associated linkages, the group concluded that it remained valid in the form presented in the 1983-84 BEMP report. However, a fourth link was added between ringed seal pup production and population levels. This new link is discussed in a subsequent section and necessitated slight rewording of the hypothesis (Figure 4-1).

The following sections briefly discuss studies conducted since the last workshop that are relevant to each link in this hypothesis. Two of the research programs described in Appendix A (Project Overviews No. 13 and 14) were considered directly applicable to the hypothesis, while several other studies involve censusing techniques that may be applied in future to investigations directed at seal populations in the Beaufort region.

REVIEW OF LINKAGES AND RELEVANT RESEARCH

Link 1: Icebreaking vessels operating in the landfast ice and through Amundsen Gulf will decrease the amount of pupping habitat available to ringed seals.

At the previous BEMP workshop, this link was discussed in terms of the possibility that icebreaker traffic could destabilize the fast ice in Amundsen Gulf, and thereby reduce the amount of available ringed seal breeding habitat. It was recommended that further research on this topic be initiated to determine both the need for and suitable design of any monitoring programs. Small-scale alterations to the ice regime in a ship's path and noise-related exclusion of pupping females from the vicinity of the tracks were both considered possible, but were not expected to be regionally significant.

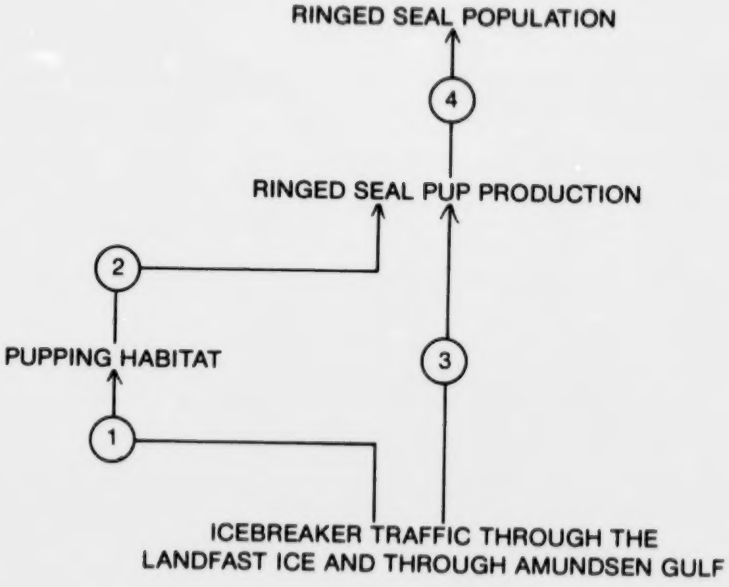
The present workshop group agreed with earlier arguments related to this link, as well as with the overall conclusions stated in the 1983-84 BEMP report. In addition, the subgroup reiterated the present uncertainties regarding the potential for large scale ice destabilization due to icebreaker traffic in Amundsen Gulf. It was noted that collection of a historical data base of satellite imagery is occurring at this time. However, the majority of the participants concluded that worthwhile research on potential destabilization of the ice cover in Amundsen Gulf will not be possible until there is some icebreaker traffic in the area.

FIGURE 4-1

POTENTIAL EFFECTS OF INCREASED FREQUENCY OF ICEBREAKER TRAFFIC THROUGH THE LANDFAST ICE AND THROUGH AMUNDSEN GULF ON RINGED SEAL PUP PRODUCTION AND POPULATION LEVELS

REVISED HYPOTHESIS NO. 4

Increased frequency of icebreaker traffic through the landfast ice and through Amundsen Gulf will reduce ringed seal pup production and population levels



Linkages

1. Icebreaking vessels operating in the landfast ice and through Amundsen Gulf will decrease the amount of pupping habitat available to ringed seals.
2. Adequate pupping habitat is necessary for the production of ringed seal pups.
3. Icebreaker traffic in late March, April and May will kill ringed seal pups.
4. Reduced ringed seal pup production will result in lower population levels.

Much of the discussion related to Link 1 focused on the possibility that single passages of icebreakers before the breeding season may marginally improve breeding habitat. It was suggested that breathing holes and lairs might be easily maintained in snow catch areas and crack zones at the edge of a ship track. On the other hand, repeated traffic in shipping corridors could cause local avoidance by female seals. It was concluded, however, that the areas of habitat that may be lost or marginally improved by icebreaker traffic would be small in relation to available ringed seal pupping habitat in the region.

Link 2: Adequate pupping habitat is necessary for the production of ringed seal pups.

An ongoing DFO (Arctic Biological Station) study of changes in the population dynamics of ringed seals in Amundsen Gulf (see Project Overview No. 13, Appendix A) was reviewed during discussion of this hypothesis link. Data analyses completed to date show no apparent relationship between pup production in Prince Albert Sound and the ice conditions in Amundsen Gulf, although it was stated that this analysis has been hampered to a certain extent by the limited amount of direct seal data from Amundsen Gulf (T. Smith, pers. comm.). Evidence was also presented that ringed seals may use unconsolidated ice to some degree as breeding habitat (Finley et al. 1983).

The relationship between ice conditions and ringed seal populations in Barrow Strait, an area with variable freeze-up chronology, are the subject of a long-term research program by T. Smith and M.D. Hammill (DFO). The working group suggested that a similar investigation, involving repeated sampling in the offshore over a number of years, would be necessary to determine the relationships between ice conditions in Amundsen Gulf and ringed seal pup production. This research was not, however, considered essential or justifiable at the present time.

Link 3: Icebreaker traffic in late March, April and May will kill ringed seal pups.

It was accepted that passage of icebreakers through areas of fast ice in the breeding season would result in mortality of some ringed sea pups, either by direct contact with moving vessels or due to flooding of birth lairs. The latter was recently studied in conjunction with the passage of the MV ARCTIC through Admiralty Inlet in June. The group expected that any losses of ringed seal pups in the Beaufort region would be small in relation to total production, and would not justify a monitoring program at the anticipated level of icebreaker traffic.

A mathematical study of the transmission of pressure waves from icebreakers under fast ice was described by one participant. The workshop subgroup concluded that a direct study of the transmission of pressure waves from icebreakers was feasible and could be completed at a very low cost to verify the model. However, this research was considered a low priority given the current development scenario and anticipated impact of icebreaking on ringed seal pups.

Link 4: Reduced ringed seal pup production will result in lower population levels.

The relationship between pup production (birth rate) and recruitment to the reproductive age classes was discussed during the evaluation of this new hypothesis link. There is frequently high mortality of sub-adult ringed seals, and this may often be due to aggression from adults rather than predation, weather or other factors. The group therefore concluded that pup production is not necessarily closely coupled with recruitment of individuals to the reproductive age classes. The strength of the relationship between pup production and recruitment, and the degree of reduction in pup production necessary to decrease recruitment to the ringed seal population remain unknown.

RESEARCH AND MONITORING

During the link-by-link review of this hypothesis, workshop participants discussed research that would substantially increase understanding of factors affecting ringed seal pup production in Amundsen Gulf and the potential impact on pupping habitat of ice cover destabilization associated with icebreaking. These studies included: (1) examination of ice processes in Amundsen Gulf, (2) investigation of the relationship between ice conditions in the Gulf and ringed seal pup production, and (3) direct measurement of transmission of pressure waves from icebreakers. Over the long-term, these and perhaps other research programs may be necessary to adequately address uncertainties related to this hypothesis. However, it was generally agreed that these programs are not a high priority until some icebreaker traffic occurs in Amundsen Gulf. On the other hand, continued collection of satellite imagery was considered essential to provide the basis for future analysis of the relationships between ice conditions and production and survival stabilization of the ice regime due to icebreaker traffic.

The present workshop participants agreed with conclusions presented in the 1983-84 BEMP report concerning the immediate and long-term need for monitoring related to this hypothesis. Initiation of monitoring should be contingent on the results of any future research programs and the actual use of Amundsen Gulf as an icebreaker transportation corridor. It was expected, however, that such monitoring would almost certainly focus on the effects of icebreaker traffic on ice destabilization and associated effects on ringed seal pup production and population levels.

LITERATURE CITED

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HYPOTHESIS NO. 5

ICEBREAKER TRAFFIC IN THE TRANSITION (SHEAR) ZONE WILL REDUCE BEARDED SEAL PUP PRODUCTION

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INTRODUCTION

The bearded seal inhabits loose- and broken-ice areas, and breeds on the ice surface within the transition zone of the Beaufort Sea. Since these areas are also likely to be the preferred corridors for shipping traffic including icebreakers, there is concern that icebreaking activities in this zone during late April to early May will kill some pups.

The workshop subgroup reviewed the existing statement of this hypothesis and its associated linkages, and concluded that both remained valid in the form presented in the 1983-84 BEMP report (Figure 5-1).

No investigations initiated or completed since the last workshop provided information that was directly relevant to Hypothesis No. 5. As a result, the group discussions involved a brief review of each link and evaluation of the need for research directed at this hypothesis.

REVIEW OF LINKAGES AND RELEVANT RESEARCH

Link 1: Icebreaker traffic in the shear zone during April and May will interfere with vocalizations of male bearded seals, and this will result in reduced mating success.

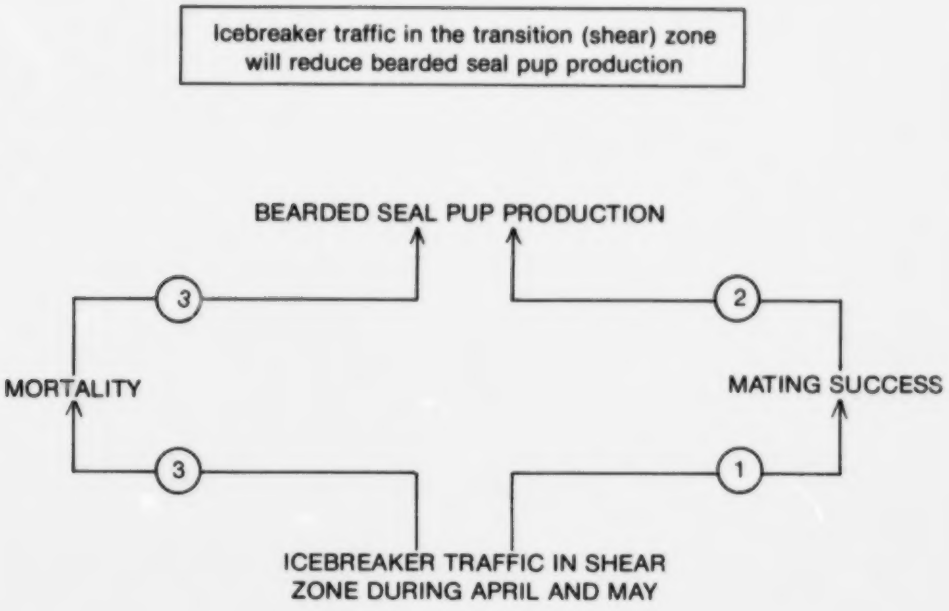
In the 1983-84 BEMP report, it was suggested that disturbances associated with icebreaker traffic could reduce vocalization rates of bearded seals during the breeding season (particularly males), or underwater noise from vessels might completely mask calls. Either of these effects could lead to reduced mating success and pregnancy rates, although it was emphasized that there is essentially no evidence to support or reject this hypothesis link. The present workshop participants concluded that little more is known at this time regarding bearded seal vocalizations and mating behaviour, or the possible effects of icebreaker traffic on these behaviours. A M.Sc. thesis by Cleator (in prep.) should provide new information on these topics.

Link 2: Successful mating is necessary for production of bearded seal pups.

As in the last BEMP workshop, this link was considered both self-evident and valid, with pup production being a function of pregnancy rate. There are almost no data on natural spatial or annual variability in bearded seal pregnancy rates in the Beaufort region. However, the group concluded that the bearded seal population in this region is too small to tolerate the degree of sampling necessary for direct evaluation of pregnancy rates. The possibility of direct estimation of pup production through photography of groups of bearded seals hauled out in summer (and subsequent counting of pups) was also discussed. It was concluded that detection of small changes in production could not be detected by this imprecise technique, and therefore, no research was recommended in relation to this link.

FIGURE 5-1

POTENTIAL EFFECTS OF ICEBREAKER TRAFFIC IN THE TRANSITION ZONE ON BEARDED SEAL PUP PRODUCTION



Linkages

1. Icebreaker traffic in the shear zone during April and May will interfere with vocalizations of male bearded seals, and this will result in reduced mating success.
2. Successful mating is necessary for production of bearded seal pups.
3. Icebreaker traffic in the shear zone during April and May will result in mortality of bearded seal pups.

Link 3: Icebreaker traffic within the shear zone during April and May will result in mortality of bearded seal pups.

As indicated earlier, the shear zone is the preferred pupping habitat of bearded seals, and will also be the preferred corridor for some shipping activity associated with hydrocarbon development in the Beaufort Sea. However, the working group agreed with the conclusion in the previous BEMP report that direct mortality of pups is unlikely to be significant. This is due to: (1) the small area of shear zone habitat that would be actually affected by icebreaking; (2) the relatively low densities of bearded seal pups in the region; and (3) the short period when they remain on the ice and would be vulnerable to icebreaker traffic. The 1983-84 BEMP report estimated that direct mortality of bearded seal pups due to icebreaking would amount to less than 20 individuals per year. Since it would be difficult (or impossible) to detect changes in pup production following losses this small, no research or monitoring was recommended to address this link.

RESEARCH AND MONITORING

A research program was recommended to provide some additional information concerning Link 1 if icebreaker traffic in the shear zone increases substantially from present levels. A study involving the use of hydrophones could be designed to determine the direct effects of icebreaker traffic on vocalization behaviour. Technological advances in hydroacoustic zoological research would allow the use of localizing arrays and voiceprints to identify and count vocalizing males. However, this research was not expected to necessarily provide information that would aid in determination of how masking or decreased vocalization rates may affect mating behaviour or success. Therefore, such research was considered a low priority in the context of the Beaufort Environmental Monitoring Project.

As indicated earlier, no research or monitoring was recommended in relation to Links 2 and 3. This was largely because the potential changes in bearded seal pup production and direct mortality, resulting from the anticipated level of icebreaking in the shear zone, were expected to be too small to detect.

HYPOTHESIS NO. 6

ICEBREAKER TRAFFIC IN AMUNDSEN GULF WILL AFFECT RINGED SEAL AND POLAR BEAR POPULATIONS

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INTRODUCTION

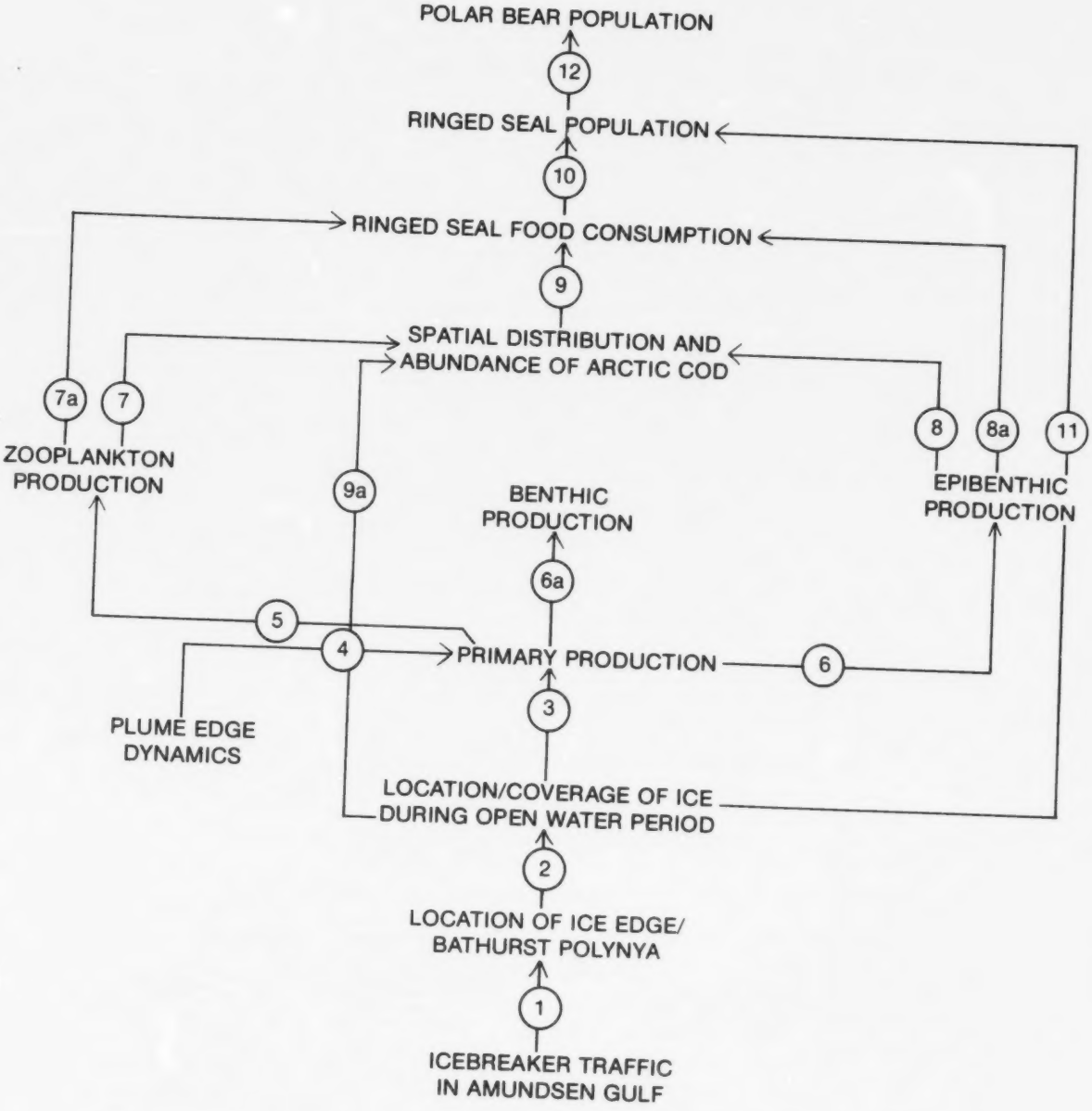
The complexity and testability of Hypothesis No. 6 were the subject of much of the initial discussion of this workshop subgroup. The hypothesis encompasses the entire trophic scale of the marine ecosystem in Amundsen Gulf (Figure 6-1), and is thus so far reaching in its research requirements, that most studies conducted in the Beaufort Sea are relevant in some way to one or more of its linkages. However, it was noted that the magnitude of specific research and monitoring that would be necessary to fully test the validity of many of it links may be so large as to be impractical and unjustifiable at present. In addition, there was some doubt if changes in seal and polar bear populations necessary to test the validity of upper links in the hypothesis (Links 10-12) could even be detected, given expected levels of icebreaker traffic in Amundsen Gulf and the range of natural factors that may attenuate the influences of the lower links involving primary and secondary consumers in the ecosystem. The potential for icebreakers to produce changes in ice distribution on a scale measurable against the natural variability in the regime, which is caused by meteorological and hydrodynamic factors, is also presently difficult to assess. However, the group expected that Link 1 was conceivable if icebreaker traffic eventually exceeds that associated with the current hydrocarbon development scenario. Another concern is that long-term (>50 y) cycles in climate and biological characteristics of the marine ecosystem could confound any noticeable changes due to icebreaker traffic.

Preliminary discussions also focused on the potential role of arctic cod in the biological energetics of resources in the Beaufort Sea/Amundsen Gulf region, as well as the need for more information on the population dynamics, distribution and life history of this species and its importance to seals and polar bears (see Review of Linkages below).

There was also some early discussion regarding the related hypotheses that: (1) arctic cod and bowhead whales compete for available zooplankton resources in the Beaufort Sea; and (2) ringed seal populations have increased in response to greater cod productivity following the near extirpation of the bowheads by historic commercial harvests. However, a lack of baseline data prevents testing of these hypotheses. For example, it is not known if the zooplankton requirements of arctic cod and bowheads are approaching the carrying capacity of the Beaufort region, and if arctic cod populations are retarding the recruitment of bowheads. It was also noted that Hypotheses No. 1 and No. 6 are somewhat interrelated since alteration of habitats in Amundsen Gulf (due to icebreaking) may change bowhead whale distribution and migration patterns in the Beaufort Sea.

FIGURE 6-1

POTENTIAL EFFECTS OF ICEBREAKER TRAFFIC IN AMUNDSEN GULF ON THE RINGED SEAL AND POLAR BEAR POPULATIONS



Linkages

1. Icebreaker traffic in Amundsen Gulf will move the stable ice edge to the east (and alter the Bathurst polynya) in winter and spring.
2. Movement of the stable ice edge may in turn change the total amount of open water in the region.
3. The coverage thickness and location of ice determine the level of primary productivity.
4. Primary production is enhanced (perhaps in patches) near the Mackenzie River plume edge.

5, 6 and 6a. The level of primary productivity determines the level of secondary productivity in zooplankton, epibenthos and benthos.

7, 8 and 9a. Distribution and production of zooplankton and epibenthos and the location of ice determine the production and distribution of arctic cod.

10. Quality and quantity of food determine ringed seal survival and mortality.
11. Location and type of ice are important in determining ringed seal distribution.
12. Numbers of polar bears are determined by numbers of ringed seals.

REVIEW OF LINKAGES AND RELEVANT RESEARCH

Link 1: Icebreaker traffic in Amundsen Gulf will move the stable ice edge to the east (and alter the Bathurst polynya) in winter and spring.

Link 2: Movement of the stable ice edge may in turn change the total amount of open water in the region.

The working group concluded that these links were valid given the maximum number of icebreaker passes through Amundsen Gulf (i.e., approximately 50 per month during peak production). The mechanics of the physical processes involved in the formation of this ice arch and the impact of its alteration are described in some detail in the 1983-84 BEMP report.

At present no new research is being planned for the Beaufort Sea which would provide information that could be used to evaluate the validity of Links 1 and 2. However, two research programs presently nearing completion may contribute some information relevant to evaluation of the validity of these links.

The first of these programs, conducted by R. Ninnis of the University of British Columbia, consisted of comparisons of Amundsen Gulf ice-edge boundary shapes apparent from Landsat satellite imagery, with the predictions of a corrected version of an earlier theory of edge shape by Sodhi (1977). Although some conclusions could be reached on the limiting factors in edge formation, frequent large deviations from the predicted parabolic shape edge and the necessity for very simplified forcing assumptions, precluded any immediate direct application of the results of this study to evaluation of Links 1 and 2.

The second program (Marko et al. 1985) used sequences of digitally-processed NOAA imagery to produce time-lapse movies of ice flow adjacent to a similar ice arch in Lancaster Sound. Again, while a significant amount of information on ice movement and mechanical properties resulted from this research, extension of measurements to data from other years and periods prior to formation of the ice edge would be required (with accompanying ground-truthing) before meaningful applications to the ice stability hypotheses and the evaluation of Links 1 and 2 could be contemplated.

Link 3: The coverage thickness and location of ice determine the level of primary productivity.

Link 4: Primary production is enhanced (perhaps in patches) near the Mackenzie River plume edge.

The group concluded that these two links remained valid. Although no new research is planned to directly address this part of Hypothesis No. 6, some information obtained in relation to linkages 5, 6 and 6a (see below) may prove useful in determining the validity of Link 4.

Links 5, 6, 6a: The level of primary productivity determines the level of secondary productivity in zooplankton, epibenthos and benthos.

A study of Mackenzie Shelf fisheries habitat initiated in 1984 by the Freshwater Institute (DFO) and continuing until 1988 (see Project Overview No. 30; Appendix A) is only partially relevant to these links because its emphasis is not on areas of open water. *In situ* primary production and chlorophyll *a* will be measured at the surface and various depths in the water column at different locations and times within and outside the Mackenzie River Estuary. This research program will also include: (1) collection of epibenthic invertebrates, macrobenthic infauna, icthyoplankton and fish, (2) evaluation of sea surface temperature and turbidity patterns through the use of NOAA satellite imagery, and (3) analysis of the relationships between zoobenthos, zooplankton and icthyoplankton biomass, and chlorophyll *a* and primary productivity levels. The workshop subgroup concluded that this project will aid in elucidation of

many of the interrelationships between primary and secondary production in areas where the research is focused, but expected that these relationships may be substantially different in deeper offshore waters in the eastern Beaufort Sea and in Amundsen Gulf.

Links 7, 8 and 9a: Distribution and production of zooplankton and epibenthos and the location of ice determine the production and distribution of arctic cod.

The ongoing DFO research program directed at the Mackenzie Shelf region will also provide information relevant to these hypothesis links. Studies of the seasonal and spatial distribution and density of arctic cod young-of-the-year were initiated in 1984, and will be expanded this year to include analysis of arctic cod stomach contents. In 1985, zooplankton will be sampled with 80 μ mesh size Wisconsin-type nets to relate food abundance to arctic cod size, abundance and growth over the summer.

Although studies in 1984-85 are restricted to the trawling of open water and ice-edge habitats, it is expected that sampling may be feasible from the ice surface during subsequent summer field seasons. This will allow examination of the distribution and abundance of arctic cod in relation to ice types and concentrations. In addition, open water and through-the-ice hydroacoustic surveys are planned in 1986-87 to estimate arctic cod biomass in various parts of the study area. The latter type of through-the-ice hydroacoustic research will begin this spring near Resolute Bay and is expected to continue into the open water season within Lancaster Sound.

Links 7a, 8a and 9: Spatial and temporal patterns in the abundance and distribution of arctic cod, epibenthos and zooplankton determine ringed seal food consumption.

During the review of these links, the subgroup recommended that the above arctic cod research near Resolute Bay be completed in collaboration with studies of seal bioenergetics that are being conducted in the same area (T. Smith, DFO, Arctic Biological Station). Information relevant to these links could also be obtained through calorimetric analysis of various year classes of arctic cod collected at different sites in the Central and Western Arctic during spring, fall and winter periods.

In addition, LGL Limited is presently conducting an analysis of existing biological material and samples to obtain information on the ecology of arctic cod and its importance to seabird and marine mammal populations. Existing specimens of arctic cod, especially samples of cod or their otoliths obtained from the stomachs of various predators (white whale, ringed seal, harp seal, narwhal, fulmar, thick-billed murre, kittiwake, etc.), are being examined during the course of this project. The study is expected to provide additional information on year class strength, seasonal and annual variability in abundance, annual variability in growth, diet (primarily of young-of-the-year), common metazoan parasites, and various life history parameters such as age of maturity, weight/length relationships and mortality (to be established from the apparent abundance of different year classes).

Information on the role of this species in the diets of its predators is relevant to any impact hypothesis that involves either direct or indirect linkages (through trophic relationships) between industrial development activities and key species of marine mammals or seabirds. This study is particularly relevant to Links 7, 8 and 9 of Hypothesis No. 6, since information may be obtained on spatial and temporal patterns in the abundance and distribution of arctic cod, which in turn affect ringed seal food consumption, seal population dynamics and therefore polar bear populations. However, the study will result in very limited new site-specific data for the Beaufort Sea/Amundsen Gulf region due to the small number of samples available for analysis from this area.

The final report will contain a description and interpretation of new information resulting from the analyses, as well as a synthesis of present knowledge regarding the ecology of arctic cod and its trophic relationships within arctic ecosystems. A number of recommendations for future research will also be provided in the final report. These recommendations are expected to be in the form of discrete hypotheses, some of which may require field research programs to test.

The group also considered the relationship between arctic cod and bowhead whales. D. Schell of the University of Alaska and M. Dunbar of McGill University have hypothesized that: (1) arctic cod and bowheads compete for Beaufort Sea zooplankton resources, or (2) ringed seal populations have increased in response to greater cod productivity following the near extirpation of the bowheads. As indicated earlier, it is not known whether the zooplankton demands of cod and whales are approaching the carrying capacity for this region, or if cod populations are retarding the recruitment of bowheads. However, the group concluded that the existing database was inadequate to test either hypothesis.

It was noted that any improvement in understanding of the general processes that govern the distribution and abundance of arctic cod and their availability to predators will increase our ability to design adequate environmental monitoring programs to accompany hydrocarbon development in the Beaufort Sea.

Link 10: Quality and quantity of food determine ringed seal survival and mortality.

Link 11: Location and type of ice are important in determining ringed seal distribution.

Link 12: Numbers of polar bears are determined by numbers of ringed seals.

These links are expected to remain valid, although there was some question of whether potential changes in the population size of seals and polar bears resulting from icebreaker traffic could be measured given the normal background variability in the sizes of these populations. Studies of ringed seals (Arctic Biological Station) and polar bears (CWS) will be continued, and the data from these programs may prove useful in future evaluation of Links 10 to 12.

RECOMMENDATIONS

The workshop subgroup identified two general concerns regarding the availability of fundamental data on the ice cover of the Beaufort Sea and Amundsen Gulf. Firstly, the present limited extent of communication between life science specialists and ice scientists was believed to be limiting the value of existing research programs. It was recommended that increased cross-disciplinary contact between these groups be encouraged.

Secondly, no effort is presently being directed at assuring the continued availability of low cost ice data such as daily, full resolution NOAA satellite imagery. These products would provide an essential database for program design and subsequent analyses in monitoring programs directed at testing of BEMP Hypotheses No. 1, No. 2 and No. 4. They also provide the least expensive long-term time series data on surface advection in the Beaufort region. This advection record could be relevant to almost any study directed at linkages 1 through 12 in Hypothesis No. 6.

It was recommended that increased cross-disciplinary contact between ice specialists and biologists be encouraged, perhaps through quasi-formal or informal working groups. Efforts should also be made to ensure that sea ice data collection and analyses are continued to the extent required for the optimal interpretation of the results of biological studies. This may require fiscal support of the continued production of satellite imagery (by AES or posssibly CCRS). Quality control and proper storage would also have to be provided to assure that imagery is appropriate and available for future research or monitoring programs. Summary catalogs of available imagery should be prepared for future access by researchers in the Beaufort region.

LITERATURE CITED

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Sodhi, D.S. 1977. Ice arching and the drift of pack ice through restricted channels. Cold Regions Research and Engineering Lab. Rep. 77-18. 11 pp.

HYPOTHESIS NO. 7

THE PRESENCE OF ACTIVE FACILITIES WILL RESULT IN INCREASED POLAR BEAR MORTALITY

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Nicholas Sonntag
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INTRODUCTION

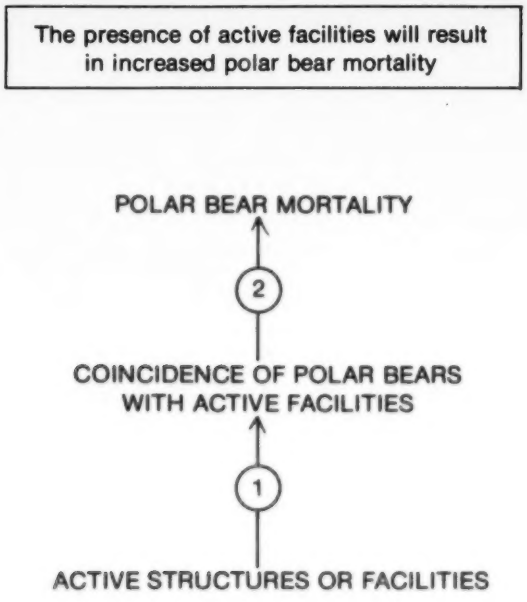
After examination of this hypothesis and its linkages (Figure 7-1), the working group concluded that both remained valid and required no changes from information presented in the 1983-84 BEMP report. Information available since the last workshop substantiated the concerns identified in the previous BEMP report that when polar bears occassionally encounter drilling rigs and other petroleum industry facilities, some animals (particularly subadult males and hungry individuals) may then be attracted to these sites by visual and/or olfactory cues. Bears that gain access to work areas around facilities are considered a threat to human safety, and therefore must either be deterred or destroyed. Although the need to destroy problem bears occurs infrequently in the Beaufort region, it is still perceived as a potentially significant additive mortality factor in the polar bear population, augmenting natural mortality and population decreases associated with the native harvest. Since it is thought that the harvest of polar bears by the Inuit is presently at its maximum sustainable level, significant additional mortality through the need to destroy problem bears, could necessitate a reduction in present quotas.

The significance of seal attraction to offshore sites as a factor that may then contribute to the attraction of polar bears was a subject of further discussion during the 1985 BEMP workshop. However, this potential phenomenon and its contributing factors remain highly speculative at present. Reduced ice cover, persistent open water and increased biological productivity around exploration or production platforms may all contribute to higher densities of seals, which in turn could result in the attraction of polar bears. However, there has been no evidence in support of this phenomenon since the last BEMP workshop.

The converse of Link 1, that some polar bears will be excluded from the area around drilling platforms, was also discussed during the present workshop. The group expected that certain sex-age classes of polar bears will be excluded from or will avoid areas of intense industrial activity. This has been documented at Churchill, Manitoba, where adult males (in contrast to subadult males and females) rareiy enter the town or forage in the garbage dump. Exclusion of bears from preferred hunting areas could adversely effect their energy balance and survival. Workshop participants concluded that exclusion was unlikely to be a serious problem at current levels of industry activity in the Beaufort region, although the issue should be noted as an area of possible concern if exploration activities increase substantially from their present level as hydrocarbon production proceeds.

FIGURE 7-1

POTENTIAL EFFECTS OF ACTIVE FACILITIES ON POLAR BEARS


The presence of active facilities will result in increased polar bear mortality
POLAR BEAR MORTALITY
2
COINCIDENCE OF POLAR BEARS WITH ACTIVE FACILITIES
1
ACTIVE STRUCTURES OR FACILITIES

Linkages

1. Polar bears will encounter active structures or facilities.
2. Polar bears that approach offshore structures have to be controlled, and this will result in the need to destroy some bears.

REVIEW OF LINKAGES AND RELEVANT RESEARCH

Link 1: Polar bears will encounter active structures or facilities.

No research relevant to this hypothesis link has been conducted since the study of Stenhouse and Latour (1983). However, personnel on drill rigs continue to report the coincidence of bears with offshore structures. The lower number of problem bears destroyed at sites of industry operations during 1984 (see Link 2(b)) is possibly due to the height of some rig structure walls (e.g., Gulf Kulluk> 3 m), which thereby prevents access by bears.

The group concluded that reports of wildlife sightings by personnel at offshore structures should be standardized if they are to provide useful data for assessing the validity of this link and be of general value to resource managers. The GNWT and some members of the petroleum industry have reviewed the present data collection system (information recorded, reporting procedures, etc.) and will implement a number of changes to improve data quality. A representative of industry at the workshop confirmed that preliminary steps have been taken to increase the usefulness of data in polar bear sighting reports as a result of the 1983-84 BEMP recommendations. Participants also reconfirmed the previous conclusion that incidental polar bear sightings and kills should be summarized each year.

In the only direct study of the effects of drilling facilities on polar bear distribution, Stenhouse and Latour (1983) were unable to detect any conclusive trends related to attraction or avoidance of offshore sites by bears. However, it is important to emphasize that the results of this study were likely influenced to some extent by the lack of suitable control sites in the same ice types as the experimental sites around offshore structures. The group recommended that a similar study with an improved design be initiated if there is an increase in hydrocarbon development activities in the region. Such studies could determine if offshore structures affect the distribution of polar bears. However, the development intensity that would trigger the need for this research was not discussed by the group.

Link 2: Polar bears that approach offshore structures have to be controlled, and this will result in the need to destroy some bears.

Since the last BEMP workshop, only one problem bear near an offshore industry structure had to be destroyed. In addition, considerable progress has been made in development of methods for detecting and deterring intruding bears. The following sections briefly summarize recent progress in each of these areas.

a) Detection

The microwave detection unit tested by Stenhouse (1983) appears to be an effective (off-the-shelf) unit for the detection of polar bears. In 1984 the GNWT, with support from the petroleum industry, also tested a scanning infrared instrument that detects any moving heat source. It may be possible to operate this system in a continuous automatic monitoring mode through the use of microcomputers and various hardware, thereby eliminating the need for constant viewing by industry personnel. This system is similar to that already in use for security purposes around some industrial installations in other regions. In addition, both the IR and microwave systems are unaffected by weather or light availability. The group also concluded that the IR system may be of potential use for the censusing of polar bears and supported further research and development in this area.

GNWT plans to test a third detection system which uses a narrower beam than that of microwave, and could therefore eliminate the problem of small animals (e.g., hares) triggering the detection system. Nevertheless, it was emphasized that even with the existing system, there is little reason for offshore personnel to encounter intruding polar bears.

b) **Deterrants**

Further polar bear deterrent research has also been conducted since the last workshop. A rubber bullet gun that fires a large high impact projectile was shown to be effective in deterring over 300 bears during experimental trials (Stenhouse 1983). In 1984, guns of this type were provided to industry personnel and wildlife officers in the Northwest Territories. Throughout the Northwest Territories, a total of 17 problem bears were killed in 1984, as compared to 40 in the previous year. Most of the kills occurred in the eastern Arctic. This reduction is attributed in large measure to the increased use of the rubber bullet gun, although several more years of experience will be required to confirm the effectiveness of this deterrent in decreasing problem bear kills.

The rubber bullet gun is not an ideal deterrent because of its short effective range, poor accuracy, the need for special training of personnel, and the potential injury of bears. As a result of these limitations, there was continued research in 1984 on the use of plastic slugs fired from a 12 gauge shotgun. These firearms are also widely available and familiar to most northerners. However, the preliminary results of this research were not encouraging because the plastic slugs did not have sufficient impact on bears at long distances, and tests with bear carcasses indicated that the slugs may injure animals at close range.

Experiments were also conducted on the use of recorded sound as an active deterrent. Ultrasound proved ineffective in deterring polar bears, while encouraging results were reported with sound at a lower frequency range of 1 to 2 KHz.

RESEARCH AND MONITORING

The workshop subgroup reconfirmed support for the recommendations provided in the 1983-84 BEMP report. Participants also elaborated on several aspects of past recommendations.

Opportunities for Linking Studies

The group concluded that ongoing and new deterrent research should continue with a high level of support and priority. Although desirable, it was considered doubtful that study integration could occur except in areas such as Churchill, Manitoba, where there are relatively high bear densities and different equipment can be tested simultaneously.

It appears that the IR system has a wide range of application for mammal detection, and therefore should be tested on several species and under varying conditions. It is unlikely that there would be any value in attempting to coordinate all possible uses of this technique, since competing interests of various researchers could hamper future development of the systems. Nevertheless, further testing of IR devices with polar bears, both as a detection and censusing technique, was recommended by the subgroup. The concept of linking deterrent and detection methods was also discussed among participants, including the potential for programming of the microwave detection unit to activate a sound-generating deterrent device.

Gaps in the Hypothesis

A potentially serious uncertainty in Link 1 of this hypothesis relates to the fact that not all bears encountering offshore structures are subsequently attracted to these facilities. It was expected that different sex or age classes of polar bears will react to offshore structures in different manners, although this may be difficult to detect or adequately measure. A study to examine potential sex- or age-specific variability in the attraction or avoidance responses of polar bears was not considered necessary at the present level of hydrocarbon development, but the need for further research in this area should be re-examined if significantly more offshore structures are envisioned in the future.

The polar bear movement study of the National Science Foundation, U.S. Fish and Wildlife Service, GNWT and CWS has peripheral relevance to this hypothesis insofar as it will determine seasonal movements of bears relative to ice types. This information could be used to determine if there are future marked changes in polar bear movement patterns. One important conclusion of this study is that the range of the Beaufort Sea polar bear sub-population extends along the mainland coast from Barrow, Alaska to Cape Dalhousie, NWT.

The unknown status of the Alaskan Beaufort polar bear harvest is a major gap in knowledge that has implications to Hypothesis No. 7. Because the Beaufort sub-population ranges throughout coastal areas of Alaska, the Yukon and Northwest Territories, it would be difficult or impossible to monitor the status of the population without knowing the extent of the Alaskan harvest. The fact that the Alaskan subsistence hunt focuses on female polar bears with cubs (Schliebe 1984) increases the degree of concern related to this harvest. It was emphasized that declining numbers of polar bears in the Beaufort Sea might be incorrectly attributed to either the Canadian harvest or industrial impacts. Future BEMP workshops and resultant recommendations should therefore address this serious gap in understanding of polar bear harvest levels.

LITERATURE CITED

Schliebe, S.L. 1984. Summary of Alaskan polar bear harvest characteristics 1980-1982. Proc. of Technical Workshop of the International Union Conservation of Nature Polar Bear Specialist Group, Grand Canyon, Arizona. 16-18 February 1983. Publ. by IUCN, Gland. Switzerland.

Stenhouse, G. 1983. Bear detection and deterrent study, Cape Churchill, Manitoba 1982. N.W.T. Wildlife Service. File Rept. No. 31.

Stenhouse, G. and P. Latour 1983. The effects of artificial islands on polar bears in the Beaufort Sea. N.W.T. Wildlife Service. File Rept. No. 33.

HYPOTHESIS NO. 8

OFFSHORE DEVELOPMENT ACTIVITIES WILL REDUCE THE HARVEST OF POLAR BEARS

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INTRODUCTION

The workshop subgroup agreed with the statement of the hypothesis and its associated linkages provided in the 1983-84 BEMP report (Figure 8-1). Link 1 suggests that (1) the construction of offshore islands will extend the offshore boundary of the landfast ice zone, and (2) icebreaker traffic will create physical barriers to the travel of Inuit hunters over the landfast ice. Both of these factors could then decrease the access of hunters to polar bears and thereby reduce harvest levels. Participants in the previous BEMP workshop concluded that this hypothesis was unlikely, and therefore, did not warrant any specific research or monitoring. The present group agreed with this overall conclusion and recommendation at the current level of industrial activity in the Beaufort region.

REVIEW OF RELEVANT RESEARCH

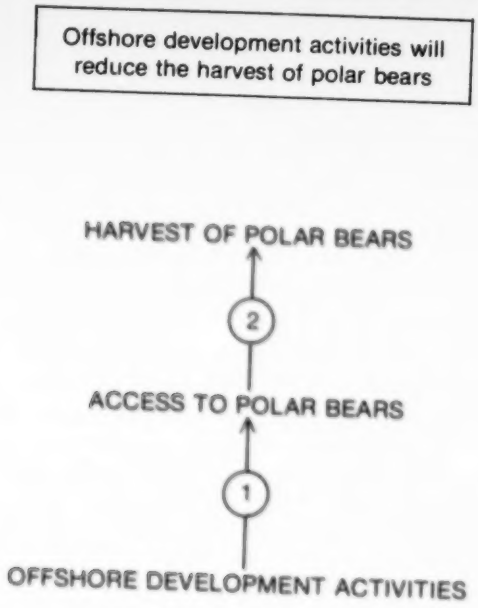
In 1984, INAC initiated a study of the effects of ship traffic on the ice regime and movements of Inuit hunters in Admiralty Inlet just prior to breakup (Strandsburg et al. 1985). The results of this research suggest that the track left by a vessel could hamper Inuit travel during about a 2-week period before breakup. However, the polar bear harvest season in the Beaufort Sea ends on May 31, and before this date, the track left by an icebreaker would quickly re-freeze and stabilize (Danielewicz et al. 1983). As a result, icebreaker tracks are unlikely to hamper hunter travel over the landfast ice in this region during the period when polar bears are harvested.

Tuktoyaktuk is the only Western Arctic community that would be affected by potential reductions in the accessibility of polar bears. However, since the polar bear harvest quota has been filled almost every year since the quota system was initiated in 1968, there is no evidence that past offshore activities have decreased the ability of Inuit hunters to harvest polar bears.

As indicated earlier, the group concluded that no research or monitoring was necessary to address Hypothesis No. 8 at present levels of offshore industrial activity in this region. Nevertheless, concern was expressed regarding the feasibility of interpreting the results of any monitoring that may be required in the future. The results of a joint American/Canadian study of polar bear movements indicate that the polar bears along the mainland coast of the Beaufort Sea from about Point Barrow (Alaska) to Cape Dalhousie (NWT) are part of a sub-population that is distinct from the bears of the Amundsen Gulf region. The mainland coast sub-population is subjected to an unregulated subsistence hunt in Alaska. It was emphasized that this subsistence harvest is focused on female polar bears and cubs (Schliebe 1984), and could adversely affect the sub-population as a whole. The group concluded that unless this hunt is carefully monitored, it will be impossible to assess if reductions in abundance and accessibility of polar bears to hunters are attributable to the hunt, offshore hydrocarbon development in the southeastern Beaufort Sea or a combination of factors.

FIGURE 8-1

POTENTIAL EFFECTS OF OFFSHORE DEVELOPMENT ON POLAR BEAR HARVEST



Linkages

1. Hunter access to polar bears will be reduced because offshore development will cause bears to move farther offshore and/or create physical barriers to Inuit travel on the ice.
2. Reduced access to polar bears will lead to reductions in the Inuit harvest of polar bears.

RESEARCH AND MONITORING

At the present level of offshore activity by the petroleum industry in the Beaufort Sea, it was concluded that this hypothesis is unlikely. Accordingly, no specific research and monitoring requirements were identified for polar bears in the region. However, the group emphasized its recommendation concerning the need for monitoring of the Alaskan subsistence harvest.

LITERATURE CITED

Danielewicz, B., E. Pessah and S. Cornett. 1983. Field investigations of tracks left by icebreaking vessels. Unpubl. Rept. by Dome Petroleum Limited.

Schliebe, S.L. 1984. Summary of Alaskan polar bear harvest characteristics 1980-1982. Proc. of Technical Workshop of the International Union Conservation of Nature Polar Bear Specialist Group, Grand Canyon, Arizona. 16-18 February 1983. Publ. by IUCN, Gland, Switzerland.

Strandsburg, A.G., U. Embacher and L. Sagriff. 1985. Spring ice breaking operations of the ship M.V. ARCTIC and concurrent Inuit hunting in Admiralty Inlet. Unpubl. Rept. prep. by FMS Engineers and Canarctic Shipping Ltd. for Northern Environment Directorate, INAC, Ottawa, 57pp.

HYPOTHESIS NO. 9

CHRONIC/EPISODIC OIL SPILLS RESULTING FROM NORMAL HYDROCARBON DEVELOPMENT ACTIVITIES WITHIN AND ADJACENT TO THE MARINE ENVIRONMENT WILL RESULT IN LOCALIZED MORTALITY OF POLAR BEARS

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INTRODUCTION

The workshop subgroup responsible for the review of this hypothesis concluded that (1) the linkages presented in the 1983-84 BEMP report required no modification, and (2) the hypothesis itself remained valid. As indicated in Figure 9-1, hydrocarbon development in the Beaufort region will result in chronic/episodic oil spills (Link 1), and direct contact of oil by polar bears (Link 2) or ingestion of oil-contaminated seals or marine birds (Link 3) may then result in mortality of some individuals in this population (Link 4).

REVIEW OF LINKAGES AND RELEVANT RESEARCH

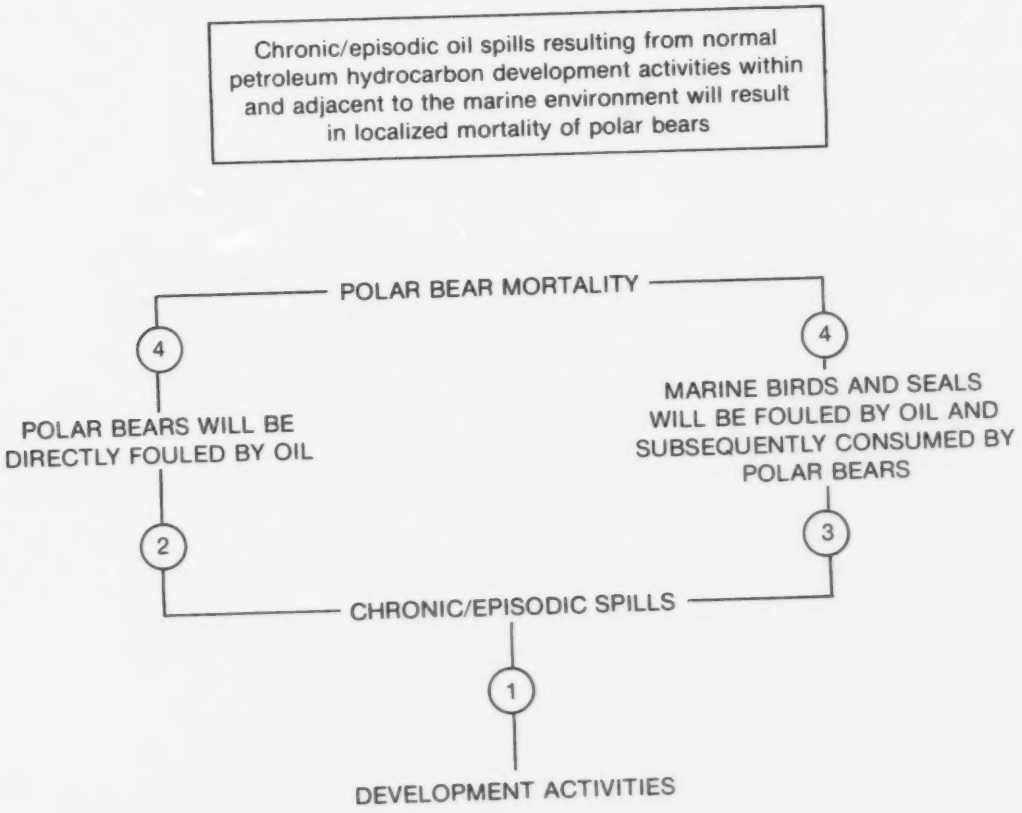
No research during 1984-85 was specifically directed at oil-polar bear interactions, although new information of relevance to this hypothesis was available from several sources.

Link 1: Development activities will result in chronic/episodic oil spills.

Chronic oil spills occur to some degree in all hydrocarbon exploration and production regions throughout the world. However, most spills are of a relatively small volume and occur infrequently. During 1984-85, a total of 38 minor spills were reported by Dome Petroleum Limited, Gulf Canada Resources Inc. and Esso Resources Canada Limited in conjunction with their exploration activities in the Beaufort Sea. The size range and location of these spills are identified in Table 10-1, although it is important to note that not all of these small numbers of spills occur offshore or reach the marine environment. For example, five of the 18 spills reported by Gulf occurred on ice where oil can be relatively easily recovered. Comparable data from support industries (e.g., transportation companies) in the Beaufort regions are not available, but are expected to also show that chronic spills occur relatively infrequently and are generally small.

FIGURE 9-1

POTENTIAL EFFECTS OF CHRONIC/EPISODIC OIL SPILLS RESULTING FROM NORMAL PETROLEUM HYDROCARBON DEVELOPMENT ACTIVITIES WITHIN AND ADJACENT TO THE MARINE ENVIRONMENT ON POLAR BEARS


Chronic/episodic oil spills resulting from normal petroleum hydrocarbon development activities within and adjacent to the marine environment will result in localized mortality of polar bears
POLAR BEAR MORTALITY
4
4
POLAR BEARS WILL BE DIRECTLY FOULED BY OIL
MARINE BIRDS AND SEALS WILL BE FOULED BY OIL AND SUBSEQUENTLY CONSUMED BY POLAR BEARS
2
3
CHRONIC/EPISODIC SPILLS
1
DEVELOPMENT ACTIVITIES

Linkages

1. Development activities will result in chronic/episodic spills.
2. Chronic spills will result in the direct fouling of polar bears.
3. Chronic spills will result in the direct fouling of marine birds and seals that are consumed by bears.
4. Mortality of bears will occur if oil is contacted or ingested.

Link 2: Chronic spills will result in direct fouling of polar bears.

Although studies conducted with captive polar bears have shown that oil contact can result in a range of adverse physiological and pathological effects that can cause mortality (Hurst et al. 1982; Oritsland et al. 1982), at the time of the previous BEMP workshop, there were no documented reports of oil contact by free-ranging bears. However, one of the present workshop participants indicated that a single polar bear with compacted oil on the neck and shoulder had recently been observed in the area of Churchill, Manitoba (I. Stirling, pers. comm.). Obvious loss of hair from the neck in the area of oil contamination was noted when this bear was tranquilized and examined. This observation confirms the earlier experimental results of Oritsland et al. (1982), who reported severe hair loss in polar bears exposed to crude oil. A sample of the contaminated hair was taken from this bear and will be analysed in an attempt to determine the origin of the oil.

Link 3: Chronic spills will result in the direct fouling of marine birds and seals that are consumed by bears.

Link 4: Mortality of bears will occur if oil is contacted and/or ingested.

No research has been conducted specifically in relation to these two linkages since the last BEMP workshop. However, the present subgroup concluded that existing evidence already substantiates the validity of Links 3 and 4.

OIL SPILL ACTION PLAN FOR POLAR BEARS

Development of a response plan in the event of a marine oil spill has advanced since the previous BEMP workshop. A document titled "Action Plan for Protection of Polar Bears in the Event of a Major Oil Spill" has been prepared by federal, territorial and provincial polar bear biologists. It has now received final review by the Polar Bear Technical Committee and is soon to be released by the GNWT. The document is designed as an Action Plan to be integrated with existing government and industry oil spill contingency plans. Emphasis is placed on being in a position to either (1) deter polar bears before they contact oil, or (2) capture and treat oil-contaminated bears. Members of the workshop subgroup encouraged publication of this Polar Bear/Oil Action Plan as soon as possible. The group also recommended continued support of polar bear deterrent research (see Hypothesis No. 7)

There was also discussion of the need to extend the objectives of such an Action Plan to include a component involving effects monitoring of "spills of opportunity". During a recent workshop designed to determine DFO Western Region research and monitoring priorities under the NOGAP program, the second highest monitoring priority was the "Opportunistic Study of the Effects of Oil Spills on Marine Mammals and Other Biota" (Thomas and Duval 1984). The present group supported the need for a plan that: (1) identifies a scientific team to respond to spills of opportunity, and (2) provides a clear description of what and how monitoring should be initiated (including asscciated research) in the event of a spill. Although it was recognized that the above Polar Bear/Oil Spill Action Plan should be released in the near future, the group concluded that revisions to this or other plans may be necessary at a later date to address opportunistic research/monitoring, as well as to consider other species of marine mammals.

RESEARCH AND MONITORING

As in the previous BEMP workshop, this subgroup discussed the possible design of a research program to determine the behavioural responses of polar bears to oil-covered waters and to oil-contaminated prey. It was concluded that although such research may be technically and logistically feasible and would present little risk to test animals, it would undoubtedly encounter extreme public and political opposition. Studies of this nature were therefore considered untenable at this time.

The workshop subgroup made the following three general recommendations:

1. To continue support for research on polar bear deterrant methods.
2. To encourage the publication, and implementation as appropriate, of the "Action Plan for the Protection of Polar Bears in the Event of a Major Oil Spill".
3. To encourage effects monitoring of spills of opportunity in general, and to investigate the potential for expanding the Action Plan to include an effects monitoring component.

LITERATURE CITED

Hurst, R.J., N.A. Oritsland and P.D. Watts. 1982. Metabolic and temperature responses of polar bears to crude oil. pp. 263-280. *In:* P.J. Rand (ed.), Land and Water Issues Related to Energy Development. Ann Arbor Science, MI. 469 pp.

Oritsland, N.A., F.R. Engelhardt, F.A. Juck, R.A. Hurst and P.D. Watts. 1983 (released 1982). Effect of crude oil on polar bears. Environmental studies No. 24, Northern Affairs Program, Can. Dept. Indian Affairs and Northern Development, Ottawa, 268 pp.

Thomas, D.J. and W.S. Duval. 1984. A workshop discussion paper for the design of a program of habitat and biological surveys for the Beaufort Sea and Northwest Passage. Prep. for Fisheries and Oceans Canada by Arctic Laboratories Limited and ESL Environmental Sciences Limited. 49 pp.

HYPOTHESIS NO. 10

(Combined Hypothesis 10 and 11 from BEMP 1983-1984)

CHRONIC (EPISODIC) OIL SPILLS RESULTING FROM NORMAL PETROLEUM HYDROCARBON DEVELOPMENT ACTIVITIES WITHIN AND ADJACENT TO THE MARINE ENVIRONMENT WILL RESULT IN LOCAL MORTALITY OF CERTAIN SPECIES OF BIRDS

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INTRODUCTION

Following initial discussions of Hypotheses 10 and 11, it was concluded that these two hypotheses should be combined as indicated in Figure 10-1. The subgroup noted that Hypothesis No. 11 (Figure 10-2) was a special case of Hypothesis No. 10, and therefore, could be included as part of the more general hypothesis. In addition, participants suggested that the number of links could and should be reduced to eliminate the need for repetitive discussion of invalid or improbable linkages in future BEMP workshops. Specifically, Links 1 and 2 of Hypothesis No. 11 were excluded from the revised version of Hypothesis No. 10.

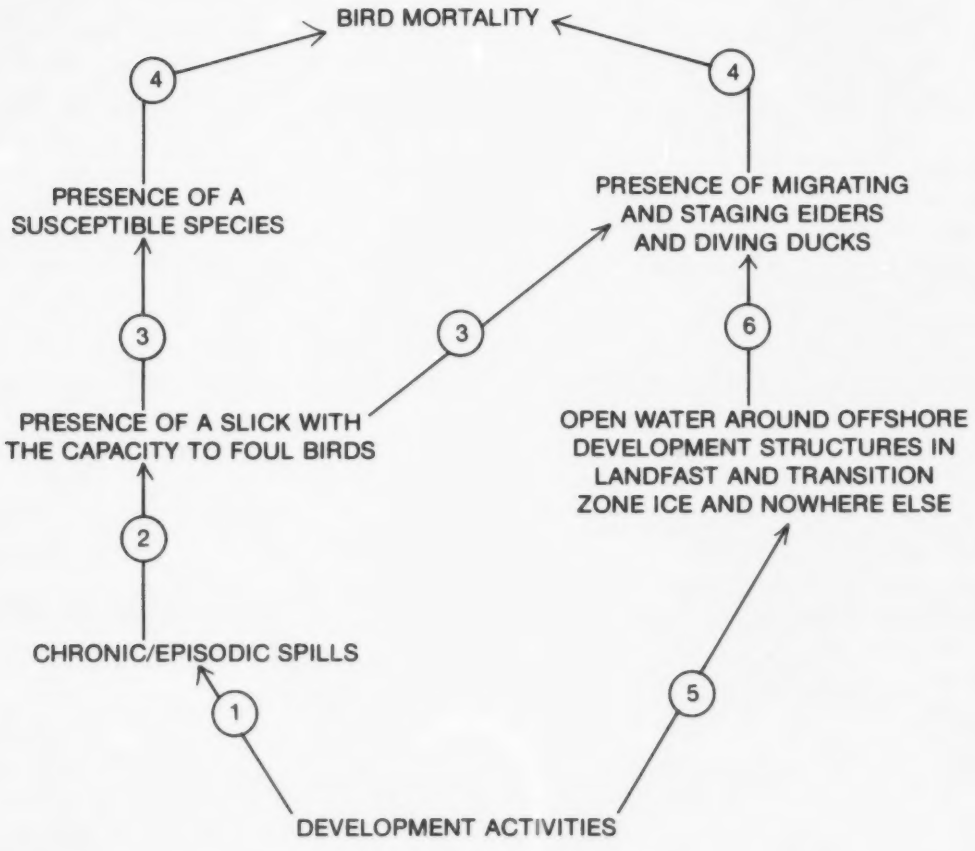
During the first phase (1983-84) of BEMP, it was concluded that particulate emissions and resulting fallout would not contribute to the formation of open water around offshore structures. Therefore, this link was eliminated from the hypothesis in the 1985 workshop. Similarly, Link 1 of Hypothesis No. 11 was removed because it was concluded that when moving ice results in the formation of open water on the lee side of offshore islands, it will also create other open water in the general areas. The subgroup recognized that open water around an island could be of significance to migrating sea ducks if there was no open water elsewhere in the region. However, when a lack of ice movement created a situation where no open water was present in offshore areas, there would also be a lack of open water around an offshore structure. Hence, this link was not considered valid in the context of the chronic oil spill situation originally addressed in Hypothesis No. 11, and was therefore eliminated during the present workshop.

Only Links 3 and 4 of Hypothesis No. 11 were retained in the restructed version of Hypothesis No. 10. In the case of new Link 5 in the present hypothesis it was recognized that the set of conditions and the manner in which thermal discharges are released from a production facility will determine the extent of any open water.

FIGURE 10-1

POTENTIAL EFFECTS OF CHRONIC (EPISODIC) OIL SPILLS RESULTING FROM NORMAL PETROLEUM DEVELOPMENT ACTIVITIES ON BIRDS

Chronic (Episodic) oil spills resulting from normal petroleum hydrocarbon development activities within and adjacent to the marine environment will result in local mortality of certain species of birds

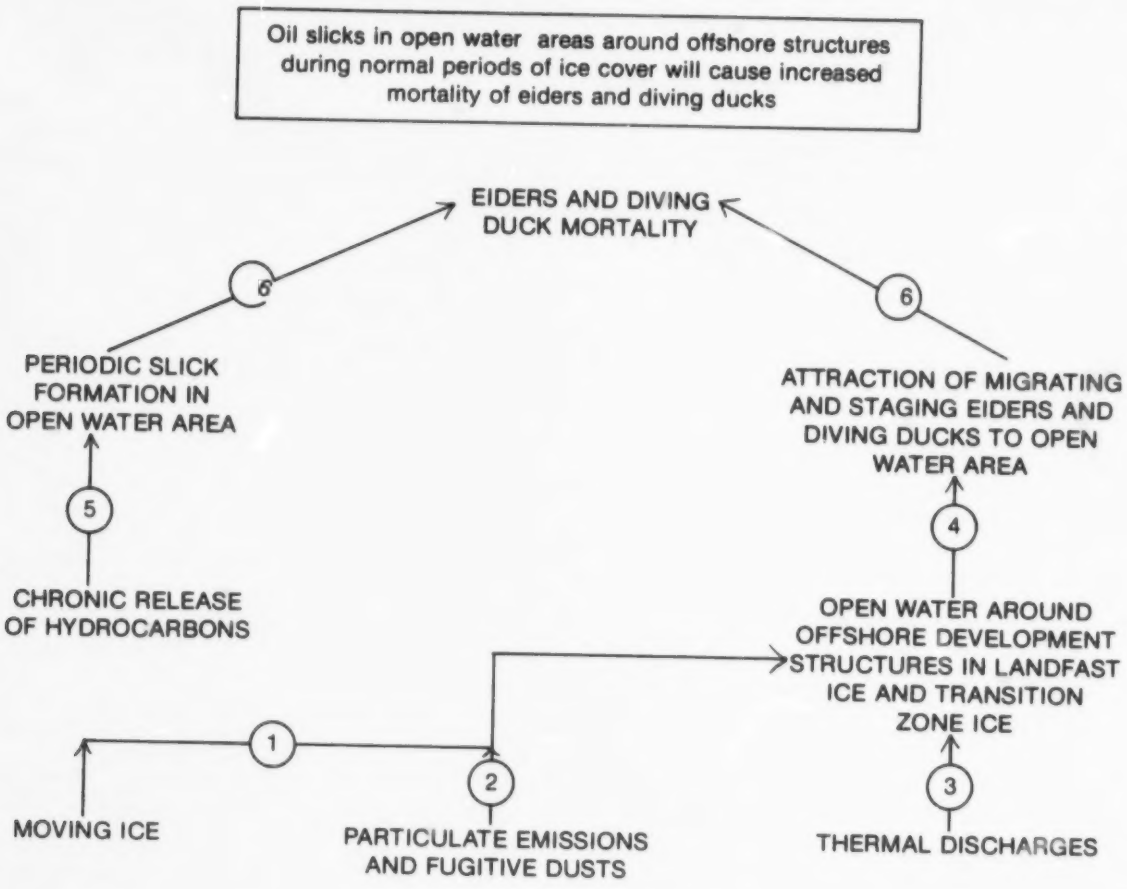


Linkages

1. Development activities will result in chronic (episodic) spills of petroleum hydrocarbons.
2. Where chronic (episodic) spills occur, slicks with the capacity to foul birds will be present under certain conditions.
3. Susceptible bird species will co-occur in space and time with the presence of a slick.
4. Mortality of birds will occur following slick contact.
5. Thermal discharges under or onto the ice from offshore production facilities will enhance melting and formation of open water around structures (Hypothesis No. 11, Link 3, 1983-84 BEMP report).
6. Eiders and other diving ducks are attracted to open water areas during migration and staging (Hypothesis No. 11, Link 4, 1983-84 BEMP report).

FIGURE 10-2

POTENTIAL EFFECTS OF OIL NEAR OFFSHORE PLATFORMS ON EIDERS AND DIVING DUCKS


Oil slicks in open water areas around offshore structures during normal periods of ice cover will cause increased mortality of eiders and diving ducks
EIDERS AND DIVING DUCK MORTALITY
6
6
PERIODIC SLICK FORMATION IN OPEN WATER AREA
ATTRACTION OF MIGRATING AND STAGING EIDERS AND DIVING DUCKS TO OPEN WATER AREA
5
4
CHRONIC RELEASE OF HYDROCARBONS
OPEN WATER AROUND OFFSHORE DEVELOPMENT STRUCTURES IN LANDFAST ICE AND TRANSITION ZONE ICE
1
2
3
MOVING ICE
PARTICULATE EMISSIONS AND FUGITIVE DUSTS
THERMAL DISCHARGES

Linkages

1. Moving ice causes rubble fields and open water in the ice surrounding offshore structures.
2. Particulate emissions and fugitive dust will decrease the albedo (increase heat absorption) of the ice, leading to increased melting and earlier formation of open water areas around offshore structures.
3. Thermal discharges under or onto the ice from offshore production facilities will enhance melting and formation of open water around structures.
4. Eiders and diving ducks are attracted to open water areas during migration and staging.
5. Chronic releases of hydrocarbons from offshore structures will cause the periodic formation of oil slicks in open water areas.
6. Oiling of birds present in open waters around offshore structures will cause mortality.

REVIEW OF RELEVANT RESEARCH

Four studies were discussed in terms of any new information they provided in relation to this hypothesis (see Project Overviews 11, 20, 21 and 24 in Appendix A). It was concluded that none of these studies provide results that change the hypothesis, its associated links or the overall conclusions presented in the 1983-84 BEMP report. For example, the research discussed in Overviews 20, 21 and 24 is relevant to catastrophic rather than chronic oil spills. One additional study was identified that will provide baseline data on birds at Herschel Island. This investigation was initiated by the Yukon Department of Renewable Resources in 1984 and will continue for the next 2-3 years or more. Although the research is being conducted in association with a designated park on Herschel Island, it will provide information on the incidence of any oiled birds in this area.

MONITORING

As a result of a previous BEMP monitoring recommendation, Dome Petroluem Limited revised its oil spill reporting form to include information on the occurrence of oil-contaminated wildlife. Most members of the working group agreed that it would be useful for all members of the petroleum industry to continue recording incidental sightings of oiled birds on spill reporting forms.

The 1983-84 BEMP report included recommendations for a fairly detailed monitoring program to document effects of incidental oil spills. This information was to be collected by spill response personnel. During the 1985 workshop, one viewpoint expressed by some participants was that such detailed monitoring is unnecessary at this time because there have been no reports of bird mortality to date following chronic spills. If mortality of birds was occurring in the region, this would have been noted by government and oil spill response personnel. It was also emphasized that bird mortality due to chronic oil spills is not considered a problem in other offshore areas (e.g., Gulf of Mexico, North Sea) where oil production has occurred for many years.

An opposing viewpoint was that a reporting system relying on incidental observations could be misleading because spill response personnel may not detect oiled birds unless a systematic approach to the examination of oil-contaminated areas is followed. It was further suggested that without a systematic monitoring program conducted by trained personnel, it is not possible to unequivocably determine whether contamination of birds has occurred.

In discussions between the session recorder and Dome's environmental operations coordinator after the group meeting, the following points were made:

1. Most chronic spills are of a relatively small volume (Table 10-1), and the larger of these spills are followed by inspections of adjacent shorelines for stranded oil. The inspections are conducted by both government personnel and inhabitants of local communities. Since the majority of chronic spills occur in coastal locations, any significant mortality of birds resulting from such events would almost certainly be reported by inspection teams.

2. Many northerners are actively employed in various aspects of petroleum industry operations in this region, and it is expected that because of the interests of native communities in protection of wildlife resources, any significant mortality of birds due to chronic spills would be reported to industry environmental coordinators, government agencies or a local Hunters and Trappers Association.

TABLE 10-1

VOLUMES AND LOCATIONS OF OIL SPILLS DURING 1984 OPERATION OF THE PETROLEUM INDUSTRY*

Locations	No. of Spills
Tuktoyaktuk Harbour+	10
Open Ocean	12
Land Spills	3
McKinley Bay	2
Wise Bay	2
Herschel Basin	9
TOTAL	38

Volumes (litres)	No. of Spills
45 and less	21
46 - 225	6
226 - 450	3
451 - 900	1
901 - 2250	1
> 2250	
TOTAL	38

* Dome, ESSO and Gulf
+ Three spills were of unknown origin; these were in the '45 and less' category

It was concluded that oil spill reports should continue to include any observations of oiled wildlife. With possible future hydrocarbon production in the region, chronic spills may increase in frequency and volume from present levels, and this may justify implementation of a systematic monitoring program related to these events. However, the frequency of spills and lack of reports of bird mortality do not appear to necessitate implementation of a monitoring program at the present time.

RESEARCH

There were no changes in the conclusions and recommendations of the workshop subgroup on research needs associated with this hypothesis from those described in the 1983-84 BEMP report. The past conclusion was that predicted hydrocarbon development levels in the Beaufort region did not justify laboratory and experimental oil spill research programs directed at birds. Rather, the management philosophy should be to scrutinize closely the results of any opportunistic monitoring of spills and to emphasize mitigative actions.

HYPOTHESIS NO. 13

SHOREBASES AND SHALLOW-WATER PRODUCTION FACILITIES WILL RELEASE HYDROCARBONS AND HEAVY METALS AT SUFFICIENT LEVELS SUCH THAT FISH HARVEST WILL BE REDUCED THROUGH TAINTING AND HEAVY METAL ACCUMULATIONS

PARTICIPANTS

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Camille Mageau
David Marmorek
Jerry Payne
Aaron Sekerak
Dave Thomas
Brian Wilson

INTRODUCTION

The consensus of the working group was that Hypothesis No. 13 (Figure 13-1) remained valid and an area of relatively high profile with respect to the Beaufort Environmental Monitoring Project, particularly those links leading from chronic hydrocarbon exposure to the tainting of fish (Hypothesis No. 13A). The potential for hydrocarbon and heavy metal contamination and subsequent decrease in the fish harvest is an area of potential concern in the Beaufort Sea region due to (1) the existing and possible expanding use of fish, and (2) experiences associated with tainting and perceived tainting in the Canadian North and elsewhere in the world.

HYPOTHESIS NO. 13A: HYDROCARBON UPTAKE

REVIEW OF RELEVANT RESEARCH

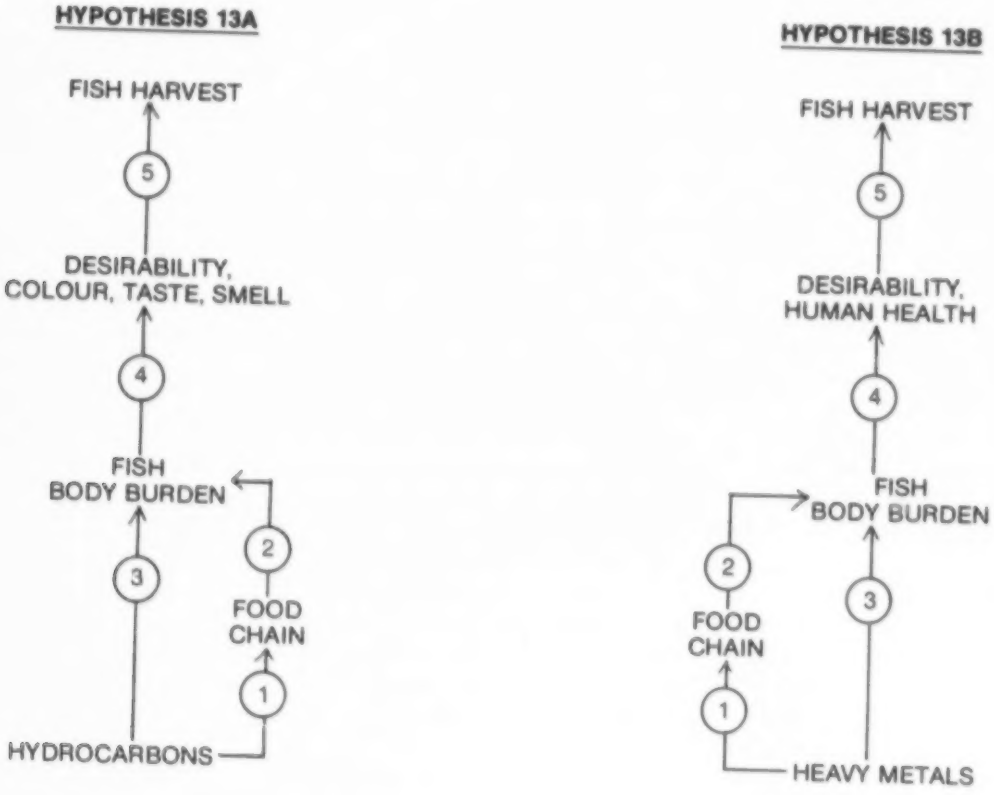
Several ongoing research and monitoring programs were considered relevant to this hypothesis and its associated linkages. Current studies are focused primarily on determination of spatial and temporal variability in the concentration of hydrocarbons and heavy metals in the sediments of the nearshore Beaufort, and around drilling activities and shipping corridors (EPS, Yellowknife; INAC, Yellowknife). Very few studies have included measurements of hydrocarbon and heavy metal concentrations in biota, although fish samples collected from Tuktoyaktuk Harbour will be analysed by DFO (Winnipeg). The results of these analyses should be available later in 1985. Future comparison of the results of EPS, DFO and INAC studies was recommended where possible to identify any areas where elevated body burdens of trace metals and hydrocarbons in biota can be correlated with contamination of sediments. At present, such comparisons would likely be limited to biota and sediments in Tuktoyaktuk Harbour.

An ESRF-funded study on tainting is presently being conducted by Martec Limited. The major objectives of this scoping study are to: (1) evaluate real or potential concerns associated with the tainting of fish resources (including shellfish) due to oil spills or hydrocarbon development activities; (2) assess the effectiveness of the various methods and procedures used to detect tainting; and (3) identify research and monitoring strategies for dealing with tainting. Case histories of fish or shellfish tainting by petroleum hydrocarbons are being documented through literature searches and communication with various national and international resource agencies, oil companies, and other individuals with expertise in this subject. An important component of the study will be the identification of fishery closures that have resulted from tainting or the threat of tainting. The second part of the review will include an evaluation of the adequacy of scientific

FIGURE 13-1

POTENTIAL EFFECTS OF RELEASE OF HYDROCARBONS AND HEAVY METALS ON FISH HARVEST

Shorebases and shallow-water production facilities will release hydrocarbons and heavy metals at sufficient levels such that fish harvest will be reduced through tainting and heavy metal accumulations



Linkages for Hypothesis 13A

1. and 3. Hydrocarbons in water and sediments will enter fish and prey organisms of harvested fish species.
2. Hydrocarbons can be passed through food chains.
4. Desirability of fish is decreased as a result of increases in body burden of hydrocarbons.
5. Decreased desirability will decrease fish harvest.

Linkages for Hypothesis 13B

1. and 3. Heavy metals from water and sediments will enter fish and prey organisms of harvested fish species.
2. Heavy metals can be passed through food chains.
4. Human health and desirability of fish can be affected by increases in heavy metal concentrations.
5. Decreased desirability will decrease fish harvest.

knowledge for addressing concerns related to tainting. This component of the investigation will involve an assessment of methods (e.g., taste panels, analytical techniques) used to resolve the problems of human perception of tainting. The merits of conducting laboratory studies with representative commercial species to determine threshold hydrocarbon detection levels and dose-response relationships, and the value of including fish tainting as a part of an overall strategy for effects monitoring at offshore oil and gas exploration and production sites are also being assessed. The results of this study are expected to be available in April 1985, and should be reviewed to determine their applicability to BEMP in general and Hypothesis No. 13A in particular.

CONCLUSION

It was concluded that tainting is likely to be a concern in sheltered bays such as Tuktoyaktuk Harbour where petroleum products are used on a daily basis, and around production platforms where hydrocarbons may be discharged as part of normal operations.

MONITORING

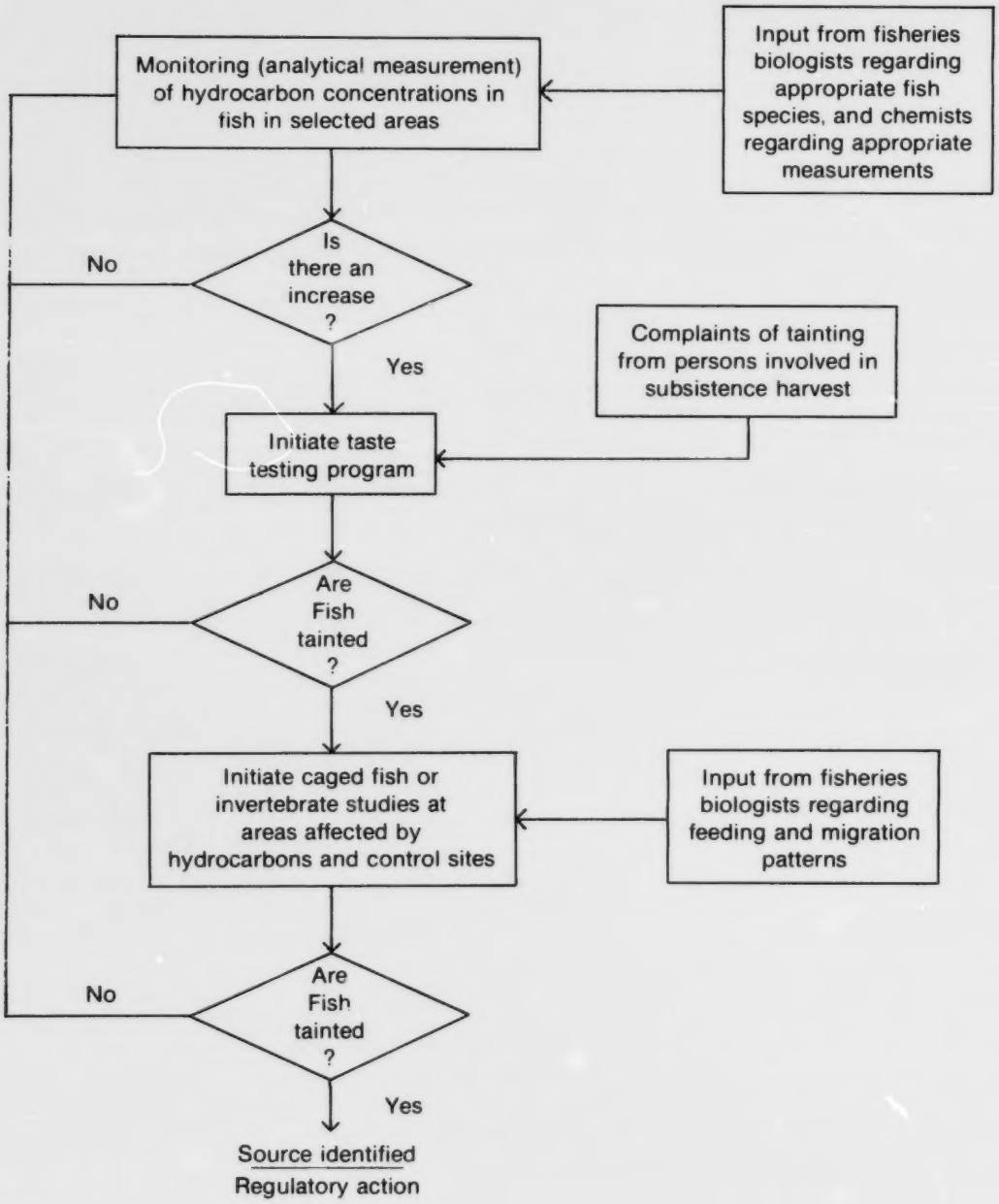
As in the previous BEMP workshop, it is recommended that a program of time series measurements of hydrocarbons in fish be initiated in Tuktoyaktuk Harbour. This monitoring should focus on a resident demersal species (e.g., arctic flounder) and a species important in terms of the subsistence harvest (e.g., broad whitefish). An inexpensive method for measurement of hydrocarbons should be used to minimize analytical costs and thereby allow anaylsis of an adequate sample size. As discussed below, mixed function oxidase (MFO) induction in fish could also provide an economical, sensitive and simple indicator of hydrocarbon exposure.

Information relevant to Hypothesis No. 13A could be gained through use of physiological/histopathological indicators which are under investigation in a number of laboratories. Most emphasis to date has focused on mixed-function oxygenases which have been validated for use in a number of field studies (e.g., Payne 1984). The perceived value of such indicators is in defining boundary limits or otherwise delineating areas of "effect/no-effect" around sites of oil spills or oil and gas developments. In addition, since physiological indices can be expected to respond to sublethal stresses well in advance of observations of impact at the population level, they can act as early warning systems of possible environmental harm.

It was also recommended that if (1) time series measurements indicate significant increases in hydrocarbons or MFO activity in fish tissue, or (2) complaints of tainting occur, complimentary programs should be considered to react to either or both of the above concerns. This recommendation was presented in the 1983-84 BEMP report and adopted by the 1985 workshop participants. Complimentary programs could consist of a taste testing program and a study to identify the size of the area where any hydrocarbon uptake/tainting is occurring. The latter investigation could involve placement of caged fish or invertebrates in experimental (sites of suspected contamination) and control areas. Research would probably be necessary to establish the actual source of hydrocarbons that was causing the tainting, although this may be difficult in relatively confined areas such as Tuktoyaktuk Harbour, where similar hydrocarbons are stored and handled at a number of locations. A flow diagram illustrating the recommended approach to this monitoring program is provided in Figure 13-2. As indicated in this diagram, monitoring or research activities other than the routine measurement of hydrocarbons in fish tissue would not be initiated unless: (1) time series measurements indicated significant uptake of hydrocarbons by fish, or (2) complaints of fish tainting occurred.

FIGURE 13-2

RECOMMENDED APPROACH TO MONITORING FOR TAINTED FISH IN TUKTOYAKTUK HARBOUR


Monitoring (analytical measurement) of hydrocarbon concentrations in fish in selected areas
Input from fisheries biologists regarding appropriate fish species, and chemists regarding appropriate measurements
Is there an increase ?
No
Yes
Complaints of tainting from persons involved in subsistence harvest
Initiate taste testing program
Are Fish tainted ?
No
Yes
Initiate caged fish or invertebrate studies at areas affected by hydrocarbons and control sites
Input from fisheries biologists regarding feeding and migration patterns
Are Fish tainted ?
No
Yes
Source identified
Regulatory action

HYPOTHESIS 13B: HEAVY METALS

REVIEW OF RELEVANT RESEARCH

Extensive and varied research has been conducted during recent years related to the health hazard associated with heavy metal contamination, particularly in the case of mercury (Knauer and Martin 1972; Hardisty et al. 1974 a,b; Liss et al. 1980; Neff 1982). It is generally believed that, with the exception of mercury and (in some cases) cadmium, heavy metals are not passed through food chains, and therefore should not represent a hazard to human health as indicated by the links shown in Figure 13-1. On the other hand, the bioaccumulation of mercury and occasionally cadmium, and the health hazard associated with exposure to these heavy metals have been well documented (e.g., NRC 1980).

CONCLUSION

Although Hypothesis 13B was considered valid for mercury and cadmium, no specific monitoring programs for heavy metal uptake by fish and other biota were recommended. The workshop participants expected that the quantities of heavy metals that would be necessary to represent an area of environmental concern were unlikely to be associated with hydrocarbon development in the Beaufort Sea, except in the immediate vicinity of production platforms where produced water containing heavy metals could be discharged.

RECOMMENDATIONS

The group expected that potential concerns related to heavy metal contamination could be adequately addressed through standardized compliance monitoring of waste streams, as well as the screening of drilling materials before selection for use in the Beaufort Sea. Future review of the results of heavy metal analyses of fish collected from Tuktoyaktuk Harbour was also recommended.

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HYPOTHESIS NO. 14

NEARSHORE STRUCTURES WILL DISRUPT THE NEARSHORE BAND OF WARM BRACKISH WATER AND REDUCE THE BROAD WHITEFISH POPULATION

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INTRODUCTION

A general review of this hypothesis indicated that it should be modified to include Links 1b and 2b as illustrated in Figure 14-1. The new links were defined as follows:

Link 1b: Nearshore structures will change the slope of the sea bottom within the brackish water band along the Tuktoyaktuk Peninsula.

Link 2b: Changes in nearshore sea bottom slope will change utilization of nearshore waters by broad whitefish.

Since broad whitefish are normally found in shallow water (i.e., <4 m deep), it was suggested that they inhabit such areas because they prefer to be located within a few meters of both the seafloor and surface. If this is the case, changes in bottom relief due to causeway construction could alter their distribution, independent of any changes in other variables such as temperature or salinity. There was no strong evidence in support of Link 2b, although it also could not be refuted on the basis of existing information. Participants from DFO stated that unpublished acoustic data collected from rivers suggest that some fish prefer shoreline areas, although major variables that might influence fish distribution (i.e., currents, food availability, depth, etc.) were not examined during this study.

REVIEW OF LINKAGES AND RELEVANT RESEARCH

Link 1a: Shoreline modifications will change temperature and salinity characteristics of the brackish water band along the Tuktoyaktuk Peninsula.

Link 1b: Nearshore structures will change the slope of the sea bottom within the brackish water band along the Tuktoyaktuk Peninsula.

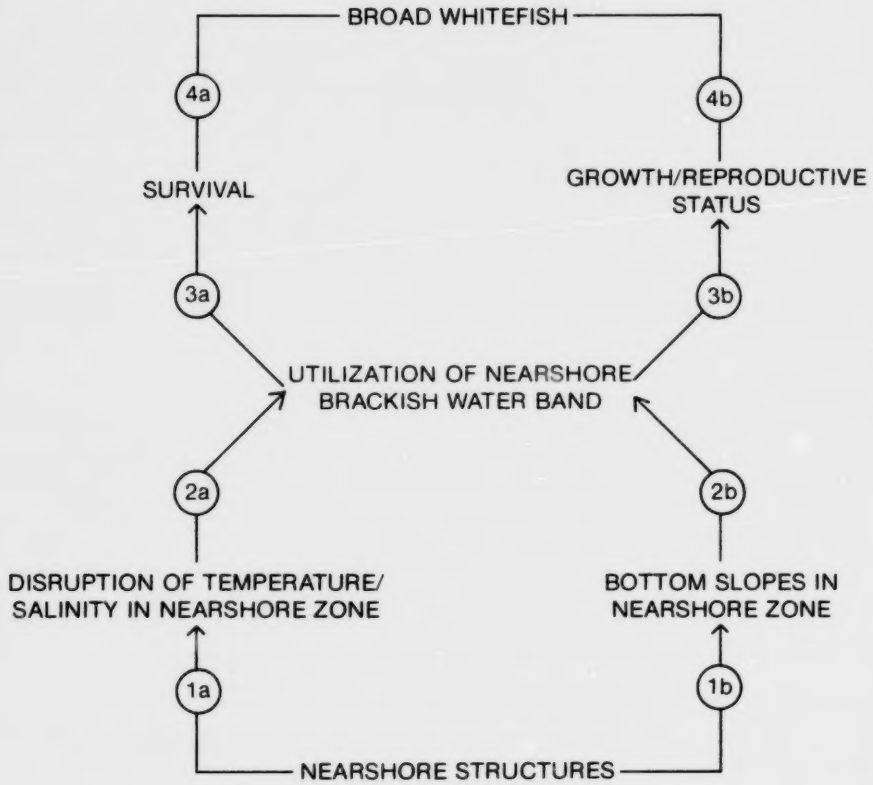
Current Research

No studies conducted in the past year directly provide information relevant to Link 1a and 1b (i.e., research directed at physical oceanographic processes in areas along the Tuktoyaktuk Peninsula with water depths of 5 m or less). However, some studies completed further offshore or in other regions were reviewed by the group because of their general relevance to this hypothesis link. These studies are briefly summarized below.

FIGURE 14-1

POTENTIAL EFFECTS OF NEARSHORE STRUCTURES ON THE ROAD WHITEFISH POPULATION

Nearshore structures will disrupt the nearshore band of warm brackish water and reduce the broad whitefish population



Linkages

1a. Shoreline modifications will change temperature and salinity characteristics of the brackish water band along the Tuktoyaktuk Peninsula.

1b. Nearshore structures will change the slope of the sea bottom within the brackish water band along the Tuktoyaktuk Peninsula.

2a. Disruption of the brackish water band will result in decreased utilization of the nearshore zone by broad whitefish.

2b. Changes in nearshore sea bottom slope will alter utilization of nearshore waters by broad whitefish.

3a. The reduced time spent in the nearshore brackish zone will cause an increase in mortality of broad whitefish.

3b. Disruption of nearshore habitat will cause a decrease in feeding time and consequently a reduction in growth and fecundity.

4a. Increase in mortality of broad whitefish would lead to a decrease in the number of spawners, and subsequent reduction in the number of harvestable fish.

4b. Reduction in fecunity and reduced viability of eggs and young would result in fewer available fish for the harvest.

Further processing and analysis of NOAA satellite imagery, in both the visible (turbidity) and infrared (thermal) bands, was completed as part of the Bowhead Whale Feasibility Study (see Hypothesis No. 1). The study involved the examination of surface water distributions in relation to surface winds over the entire eastern Beaufort Sea. The results of this research will increase general understanding of large scale ice and current patterns in the region.

A long-term investigation of circulation and water mass characteristics on the Beaufort Shelf was recently initiated by the Institute of Ocean Sciences (DFO). This study will involve numerical modelling and collection of data over a 1-year period (from April 1985) at sites on the continental shelf with water depths ranging from 20 to several hundred metres. The research is expected to substantially improve present knowledge regarding general oceanic dynamics over the Beaufort Continental Shelf. However, it is difficult to predict if this study will increase understanding of oceanographic processes in complex shallow water regions such as the Yukon coast.

A major NSERC-funded study of river plume dynamics under fast ice has been initiated by the Marine Sciences Centre of McGill University (R.G. Ingram). Although the field work for this project will be conducted in James Bay, its results may still be very relevant to this hypothesis and BEMP Hypothesis No. 15. For example, it has been suggested that fresh water from large northern rivers may flow for considerable distances under winter ice cover without mixing appreciably with underlying seawater (e.g., at least 18 km out from Tuktoyaktuk; Barber and Murty 1977). In the Beaufort Sea, this phenomemon could have wide ranging implications to both migrating or overwintering fish populations.

Workshop participants concluded that while the above research will be useful in determining large-scale and offshore oceanographic conditions, studies focused on the local, coastal processes would be required to adequately validate Link 1 in this hypothesis.

Site-Specific and Regional Considerations

The effects of any nearshore structure on broad whitefish are expected to be highly dependent on both the nature of the coastal development and physical characteristics of the shoreline environment at the sites of such facilities. The exact location and type of nearshore structure (i.e., causeway, wharf or jetty) would have a major influence on its physical and subsequent biological effects, while site-specific oceanographic conditions (e.g., seafloor slope, horizontal and vertical T/S gradients, currents) would further influence the nature and degree of physical and biological impact. The group therefore concluded that the validity of Link 1a would vary with location throughout the region. It was suggested that different areas along the Tuktoyaktuk Peninsula would vary in their vulnerability to changes in T/S characteristics due to nearshore structures because of broad regional differences in (1) the slope of the seafloor, (2) prevailing currents, and (3) spatial variability in the distribution of the Mackenzie River plume throughout the winter and summer. Studies conducted in the vicinity of the ARCO causeway in Alaska clearly indicate that nearshore structures can cause marked changes in temperature, salinity and current patterns in shallow regions of the Alaskan Beaufort Sea (WWC and LGL 1985).

Link 2a: Disruption of the brackish water band will result in decreased utilization of the nearshore zone by broad whitefish.

Link 2b: Changes in nearshore sea bottom slope will alter utilization of nearshore waters by broad whitefish.

The 1983-84 BEMP report provided a detailed review of available information on the open-water distribution patterns of broad whitefish in both Alaskan and Canadian portions of the Beaufort Sea and only a general summary is provided in this report. Studies conducted in the Mackenzie Delta area have indicated that this species generally tends to remain nearshore during the open-water season, is rarely found offshore in Kugmallit Bay, and appears to avoid even the deep waters within the Tuktoyaktuk Harbour (Bond 1982). Galbraith and Hunter (1975) also reported the presence of broad whitefish in nearshore waters along the coast of the Tuktoyaktuk Peninsula, but found no individuals in deeper offshore waters. Similarly, Lawrence et al. (1984) found that broad whitefish were restricted to the inner estuary and that the largest catches occurred along the southeast shore of Kugmallit Bay.

Broad whitefish move up the rivers on the Tuktoyaktuk Peninsula shortly after the ice disappears in early spring (May-June). There is also a downstream movement of this species beginning in about July. The individuals moving downstream tend to be larger than those moving upstream and at least some are mature spawners. As the open-water season progresses, the freshwater wedge along the Tuktoyaktuk Pensinsula becomes less defined as surface mixing brings cooler marine waters close to shore. The broad whitefish that remain in coastal waters and those that enter these waters from the peninsula lakes likely move back into the Mackenzie Delta by September. Some of the small, immature individuals appear to remain in the pensinsula lakes from 1 to 4 years before returning to coastal waters.

Current Research

Past field studies conducted in the Alaskan Beaufort have demonstrated significant positive correlations between the abundance of broad whitefish (catch per unit effort) and temperature, and inverse relationships between abundance and salinity (e.g., Griffiths and Gallaway 1982; Critchlow 1983; Griffiths et al. 1983; WCC 1984; WWC and LGL 1985). The research by WCC (1984) showed that in August 1983, broad whitefish moved out of Prudhoe Bay and into the mouth of the Pet River in advance of a cold marine water mass driven onshore by westerly winds. The most recent study in Alaska (WCC and LGL 1985) indicated that, over the 90-day open-water season, almost all of the broad whitefish (10,500) captured in the study area were taken in nets located along the mainland shore. In the case of large (>250 mm in length) broad whitefish, salinity alone accounted for 39 percent of the observed variation in distribution, while the inclusion of temperature in the analysis only removed an additional 2 percent of the observed variation (WCC and LGL 1985). The distribution of small (<250 mm in length) broad whitefish was negatively correlated with amphipod and copepod biomass, although these two factors only accounted for 7 percent of the observed variation in distribution. It is unlikely that an increase in amphipod and copepod biomass repelled small broad whitefish, but rather that some factor which caused an increase in the number of amphipods and copepods (e.g., upwellings), simultaneously repelled small broad whitefish.

The Freshwater Institute (DFO) is presently conducting broad whitefish stock distribution studies in the Mackenzie Delta. The purpose of the investigation is to determine the discreteness and number of broad whitefish stocks in the Mackenzie River drainage through morphometric, meristic and electrophoretic techniques. Samples of whitefish have been obtained in the Mackenzie Delta and at several upstream locations on the Mackenzie River. This research is of interest because it may provide data that

will aid in assessment of the possible magnitude of the effects of hydrocarbon development on broad whitefish. If separate populations of broad whitefish exist in the region, they may be more susceptible to some development activities, particularly if such populations remain as relatively discrete units while present in the Beaufort Sea.

The Freshwater Institute is contemplating studies for 1985 to radiotrack broad whitefish movements along the margins of the Beaufort Sea. This research could address major data deficiencies regarding the seasonal use of nearshore waters by broad whitefish. Current theories of fish movements in nearshore areas are based primarily on indirect evidence. Information regarding fish movements along the coast would be of greatest value if temperature and salinity data are collected simultaneously.

Additional Considerations

The distribution of broad whitefish may not be governed solely by the temperature/salinity characteristics of nearshore waters, although it is clear that this species is normally only observed in a narrow band along the shore. The workshop group considered various additional reasons for this distribution such as water depth, proximity to the shoreline, bottom slope, food availability, turbidity and light. Although there is some evidence to suggest that each of these factors may influence the distribution of broad whitefish, it is much more likely that a non-linear combination of physical and biological factors determine distribution and movement patterns. However, given the uncertainty in identifying other key physical factors governing fish distribution, the group concluded that it was still appropriate to use temperature/salinity anomalies as indicators of potential disruption of use of nearshore waters by fish, provided that the uncertainties inherent in selecting these two factors are also fully recognized.

Summary

Broad whitefish appear to be restricted to nearshore waters in both the Alaskan and Canadian portions of the Beaufort Sea. The most likely factors determining this distribution pattern were thought to be temperature and salinity, although other factors (e.g., bottom slope, food availability, water depth, currents, etc.) very likely override these primary stimuli for at least short periods of time. Regardless of the habitat factors controlling the distribution of broad whitefish, numerous studies suggest that disruption of the brackish water band in the nearshore could result in decreased utilization of this zone. Structures in the Alaskan Beaufort Sea have altered nearshore temperature, salinity and current regimes.

Link 3a: The reduced time spent in the nearshore brackish zone will cause an increase in mortality of broad whitefish.

Link 3b: Disruption of nearshore habitat will cause a decrease in feeding time and consequently a reduction in growth and fecundity.

Link 4a: Increase in mortality of broad whitefish would lead to a decrease in the number of spawners, and subsequent reduction in the number of harvestable fish.

Link 4b: Reduction in fecundity and reduced viability of eggs and young would result in fewer available fish for the harvest.

The workshop subgroup reviewed the above linkages and concluded that they all remained valid. Little new data on the growth, survival and reproductive status of broad whitefish, and how these parameters may be affected by changes in utilization of nearshore waters, has been collected since the last BEMP workshop. It was emphasized that coastal habitats likely are important to broad whitefish for different reasons depending on time of year and life history stage. Coastal regions may provide: (1) a

migration corridor, (2) feeding habitat only, (3) a migratory pathway and feeding habitat, and (4) overwintering habitat.

Current Research

A number of the studies that are being conducted or were recently completed (e.g., Lawrence et al. 1984) at the Freshwater Institute (DFO) have broad relevance to one or more of the above links, although no research in progress or planned will specifically address the uncertainties in Links 3 and 4.

A broad-based research program to delineate fish habitat on the Beaufort Shelf has been initiated by DFO. Collection of samples from shoreline areas is not included in the present program, although the absence of broad whitefish at offshore sampling sites may provide indirect evidence regarding the overall patterns of their distribution in the Beaufort Sea.

Two ongoing studies could result in some information regarding the possible effects of nearshore structures on populations of broad whitefish in terms of reduced stocks and harvests. The first study involves the radiotracking of mature broad whitefish up the Mackenzie River, determination of the area and time of spawning and subsequent downstream movements to overwintering areas. This research has been in progress for a number of years and a report describing the program results is expected in the near future.

The second study involves the use of morphometric, meristic and electrophoretic techniques to determine the number of separate populations or stocks of broad whitefish that may inhabit the Mackenzie River drainage. The number of populations that exist and their behaviour will, in part, determine if lethal and sublethal effects of development activities in nearshore waters are likely to be reflected in resource harvest levels. If small, discrete populations exist and they remain in somewhat distinct groups in nearshore waters, effects of structures on specific fisheries could be relatively severe. On the other hand, if separate stocks do not exist or if considerable mixing of stocks occurs in nearshore waters, any effects of causeways or other shoreline modifications are more likely to be distributed over several fisheries. In this situation, the likelihood of detection of changes in harvest levels would be considerably reduced.

Summary

Following a review of the current development scenario and present uncertainties in Links 3 and 4, it was concluded that further research related to these linkages is not essential at the present time. The subgroup also concluded that it is not known if relatively minor or even pronounced effects of nearshore structures could be reflected in reduced population sizes or harvest levels in specific fisheries. In addition, changes in harvest levels would be especially difficult to document due to the lack of appropriate baseline data.

CONCLUSION

The validity of Hypothesis No. 14 can not be refuted on the basis of available information. Recent studies of causeways in Prudhoe Bay indicate that nearshore structures could conceivably cause changes in the distribution of broad whitefish in the southeastern Beaufort Sea (Links 1a, 1b, 2a and 2b). However, it is uncertain if such changes in distribution would have significant implications to broad whitefish populations or their subsequent harvest (Links 3a, 3b and 4a, 4b).

RESEARCH

A brief, broadly-based study to summarize available information on the range of coastal oceanographic conditions present in the study area was discussed. Such research would aid in evaluation of the potential for causeways to disrupt nearshore temperature/salinity patterns in different subareas within the region. If subareas with specific oceanographic characteristics can be identified, then available fisheries data for these areas could be assessed and the subareas ranked in terms of their potential vulnerability to effects of nearshore structures. Most members of the working group agreed that this low level study was warranted and of value in the long term, even though causeways are not presently part of the regional development scenario.

If causeways are envisaged (e.g., in association with the ADGO field), research on nearshore oceanography and fish distribution and movement near proposed structures should be initiated as soon as possible. The group emphasized that a major difficulty in interpretation of data collected in the Alaskan Beaufort was the lack of detailed information on conditions before the ARCO causeway was constructed.

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HYPOTHESIS NO. 15

NEARSHORE STRUCTURES WILL DISRUPT THE NEARSHORE BAND OF WARMER BRACKISH WATER AND WILL REDUCE THE ALASKAN POPULATION OF ARCTIC CISCO

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Aaron Sekerak

INTRODUCTION

The links that form this hypothesis are shown in Figure 15-1. After a general review by the workshop subgroup, it was concluded that both the hypothesis and its linkages remained valid and required no modifications.

REVIEW OF LINKAGES AND RELEVANT RESEARCH

Link 1: Nearshore structures will disrupt the distributions of temperature and salinity in the nearshore zone.

Current Research

No studies conducted in the past year directly provide information relevant to Link 1 (i.e., research directed at physical oceanographic processes in areas along the Yukon coast with water depths of 5 m or less). However, some studies completed offshore or in other regions were reviewed by the group because of their general relevance to this hypothesis link. For a summary of pertinent studies, readers are referred to the discussion of Link 1 in Hypothesis No. 14.

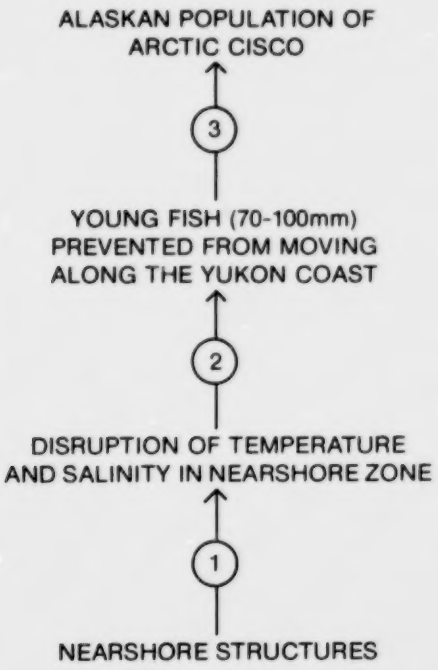
Site-Specific and Regional Considerations

Site-specific concerns associated with construction of a causeway on the Yukon coast were also discussed by the subgroup, although it was recognized that there are presently no proposals for such a structure. It became apparent from these discussions that the impacts of a causeway on water circulation, temperature and salinity would depend on local bathymetry at specific sites along the Yukon coast. For example, due to the position of the ARCO causeway in Prudhoe Bay in relation to the adjacent barrier islands, it appears to deflect westward-flowing brackish, warm water from the nearshore area out into areas beyond the barrier islands. Therefore, construction of an identical causeway elsewhere along the Beaufort coastline where no barrier islands exist may not cause the potentially detrimental changes in circulation patterns associated with the ARCO structure. The group also emphasized that adverse effects of causeways may be minimized by various engineering solutions during the design of structures. For example, broad breaches in the nearshore portion of a structure, closed by bridges, would minimize disruption of the nearshore flow and water properties. Site-specific considerations and the intended purpose of a causeway would determine the feasibility of breaches as a mitigative measure.

FIGURE 15-1

POTENTIAL EFFECTS OF NEARSHORE STRUCTURES ON THE ALASKAN POPULATION OF ARCTIC CISCO

Nearshore structures will disrupt the nearshore band of warmer brackish water and will reduce the Alaskan population of arctic cisco


ALASKAN POPULATION OF ARCTIC CISCO
3
YOUNG FISH (70-100mm) PREVENTED FROM MOVING ALONG THE YUKON COAST
2
DISRUPTION OF TEMPERATURE AND SALINITY IN NEARSHORE ZONE
1
NEARSHORE STRUCTURES

Linkages

1. Shoreline modification will change temperature and salinity patterns of the brackish water band along the Yukon Coast during summer.
2. Disruption of the brackish water band will result in decreased movement of young arctic cisco from the Mackenzie Delta to the Alaskan Beaufort Sea coast.
3. Decreased movement of arctic cisco will cause directly proportional decreases in the Alaskan population of arctic cisco.

Opportunities for Integration of Studies

There appear to be opportunities for integration of studies on two different levels. First, the previously mentioned studies (see Hypothesis No. 14, Link 1) on large-scale oceanographic conditions and responses to meteorological variables could be strengthened through greater exchange of information such as satellite imagery or other data among research groups. Second, there should be more emphasis on collection of temperature, salinity or other types of physical oceanographic data during biological field research.

Even though this additional information may be limited to specific sites and seasons, it is considered of value because of the limited amount nearshore T/S data. The group identified the lack of T/S data within a few hundred metres of the coastline as a particularly serious information deficiency at the present time.

Link 2: Disruption of the brackish water band will result in decreased movement of young arctic cisco from the Mackenzie Delta to the Alaskan Beaufort Sea coast.

Current Research

Fisheries studies conducted in the Prudhoe Bay region of the Alaskan Beaufort Sea (WWC 1984; WCC and LGL 1985) have provided information on life history patterns of arctic cisco that is consistent with descriptions in the 1983-84 BEMP report. This research suggests that: (1) the Mackenzie River drainage could be the source of the arctic cisco distributed along the Alaskan coast, and (2) these fish overwinter each year in the deltas of large Alaskan rivers (e.g., Colville, Sagavaninktok, Canning, etc.) and only return to the Mackenzie River to spawn when they are 7-9 years old. In addition, the study in 1984 (WWC and LGL 1985) suggested that small arctic cisco (<250 mm in length) did not appear to move westward around the ARCO causeway in any appreciable numbers. It is not known if this lack of movement was due to the physical presence of the causeway, the lack of consistent easterly winds that transport the warmer, less brackish water around the end of the causeway, or a natural phenomenon unrelated to winds or the presence of the structure. The results of marking programs showed that these fish had remained in the vicinity of the Sagavaninktok Delta since about 1980, and that they were smaller at a given age than arctic cisco collected near Oliktok Point and in the Colville Delta area.

A DFO fisheries study is planned to assess fish distribution and movements at a few selected sites along the Yukon coast during the open water season of 1985. The results of this research could allow future evaluation of the validity of Link 2, particularly if the study proceeds for a number of years and results in data on directional fish movement.

Additional Considerations

There was some discussion on the nature of disruptions to the nearshore band of warm, brackish water that could affect use of these waters by arctic cisco. Apparently, this species is considerably more tolerant than broad whitefish to cold marine waters, although available information suggests that it still prefers warm brackish waters (Fechelm et al. 1983; Neill et al. 1983). As a result, the local disruption of a nearshore band of warm brackish water caused by a causeway may not be lethal to arctic cisco, but less than ideal T/S conditions may lead to stress and reduced growth in some proportion of the population. Disruption of the nearshore band of water along the Alaskan and Yukon coast likely occurs naturally in response to changing wind conditions, and arctic cisco are apparently able to cope with these natural changes over the long term, even if they may represent suboptimal conditions. It is also noteworthy that year-class strength of arctic cisco in Alaskan waters varies dramatically (WCC and LGL 1985).

Link 3: Decreased movement of arctic cisco will cause directly proportional decreases in the Alaskan population of arctic cisco.

No studies that directly address this link in Hypothesis No. 15 were initiated since the last BEMP workshop. However, the previously mentioned Alaskan research by WCC and LGL (1985) provides indirect evidence in support of this link, since the western distribution of small arctic cisco could not be limited by the ARCO causeway in Prudhoe Bay. The recently initiated DFO study on the Yukon coast is also expected to aid in determination of the validity of this link. The continued monitoring of the Alaskan commercial fishery (mainly for arctic cisco) in the Colville River will also provide evidence on whether or not arctic cisco migrations are being affected by the existing causeway in Prudhoe Bay. Reductions in the commercial catch in this fishery could occur if: (1) the ARCO causeway is hampering westward migration of arctic cisco, and (2) the current theory that Alaskan arctic cisco originate from the Mackenzie River is correct.

CONCLUSION

As in the last workshop, the present group concluded that the links in Hypothesis No. 15 could not be proved or disproved on the basis of existing information, and that there was no evidence for rejection of the overall hypothesis. In fact, additional evidence in support of Link 2 strengthened the overall hypothesis. The rationale for these conclusions is summarized as follows.

Link 1: Although most aspects of the nearshore physical oceanographic regimes (e.g., T/S conditions, currents) in the southeastern Beaufort Sea are poorly documented, the group concluded that the potential for disruption of nearshore temperature/salinity patterns is probably greater along the Yukon coast than along the Tuktoyaktuk Peninsula. Under some wind conditions, the causeway in Prudhoe Bay has drastically altered temperature and salinity patterns in adjacent waters.

Link 2: While arctic cisco are known to be less sensitive than broad whitefish to high salinities, several laboratory, field and modelling studies in Alaska suggest that causeways can significantly affect arctic cisco distribution.

Link 3: It has not been conclusively demonstrated that Alaskan stocks of arctic cisco originate from the Mackenzie River system, although existing evidence supports this theory. Therefore, if Links 1 and 2 are valid, nearshore T/S alterations could result in significant reductions in the Alaskan arctic cisco population.

RESEARCH

The potential for causeways in the Canadian portion of the Beaufort Sea to affect arctic cisco distribution and movements is largely unknown. However,

1. increasing indirect evidence that causeways are affecting fish distributions in the Alaskan Beaufort; and
2. the increasing numbers of causeways that are constructed or planned in the Alaskan Beaufort; and
3. the possibility of causeway construction in the Canadian Beaufort (e.g., the ADGO field is located only a few kilometres from shore),

all increase the degree of concern related to the potential impacts of these structures on anadromous species of fish. As in Hypothesis No. 14, the group discussed a research program to assess the vulnerability of different areas from the Mackenzie Delta to the U.S./Canadian border to disruptions in current, temperature and salinity regimes from causeway construction. Even though causeways are not part of any existing development scenario, it was concluded that a low level study to examine regional differences in vulnerability was warranted at the present time.

MONITORING

Data from the Colville River fishery will continue to be available, since this information must be supplied to the Alaskan Department of Fish and Game. This is considered an extremely important monitoring program because it could document if the existing causeway in Prudhoe Bay is adversely affecting arctic cisco movement. No other monitoring related to this hypothesis was recommended by the 1985 BEMP workshop participants.

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HYPOTHESIS NO. 16

THE CONSTRUCTION OF SHOREBASES AND DEVELOPMENT OF SHALLOW-WATER PRODUCTION FIELDS WILL RESULT IN A DECREASE IN THE POPULATIONS OF ARCTIC CISCO AND BROAD WHITEFISH

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INTRODUCTION

In the 1983-84 BEMP report, it was concluded that Hypothesis No. 16 was extremely unlikely and did not justify further consideration because production facilities were expected to be located in waters deeper than 5 m. However, the hydrocarbon development scenario for the Beaufort Sea has recently changed with the possibility of production from the ADGO field, which is located in water depths less than 3 m within the Mackenzie River Estuary. The hypothesis was re-evaluated during the 1984 BEMP workshop in view of this alteration to the development scenario, as well as the availability of new information from research and monitoring programs initiated or completed during the past year. The first link of the hypothesis (Figure 16-1) was also revised to reflect the site-specific nature of this potential development at ADGO.

REVIEW OF LINKAGES AND RELEVANT RESEARCH

Link 1: Warm water effluents and production water will be discharged into the freshwater area of the outer Mackenzie Delta.

Changes in the development scenario necessitated a review of waste discharges that may be associated with production from the ADGO field. Original estimates of oil production from this field were 110 m^3 d^{-1} (692 bbl d^{-1}) for each well (LGL et al. 1984, p. 233). These estimates have been confirmed through flow rate tests of exploration wells, which are usually higher than production rates, and range from 180-500 m^3 d^{-1} (1134-3150 bbl d^{-1}). The total estimated production from the ADGO field is presently estimated at between 1500-4000 m^3 d^{-1} or 10,000-25,000 bbl d^{-1} (E. Caldwell, Esso Resources Canada, pers. comm.). It is also expected that 10 to 20 wells clustered on two production islands may be required to produce the field.

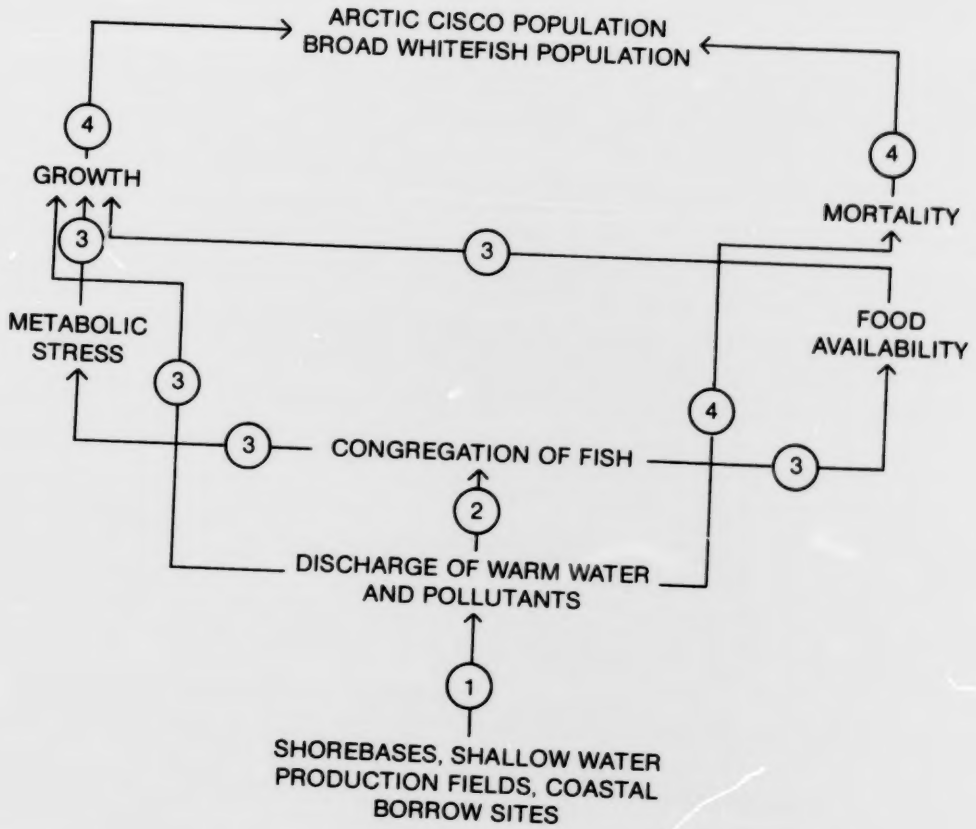
For the purposes of estimating the volume of waste discharges, it was assumed that produced water volumes would be equivalent to rates of oil production over the life of the field (i.e., 750-1000 m^3 d^{-1} per platform). It was recognized, however, that actual rates of produced water discharge will vary with a number of operational factors including injection rates and volumes of oil recovered. On the basis of data provided in Thomas et al. (1983), the concentrations of oil and grease in produced water were assumed to be approximately 50 mg L^{-1}, although higher levels may occur for short periods. This produced water was also expected to be highly saline and contain some heavy metals, but the concentrations of heavy metals that could be present in formation water from this part of the Beaufort Sea were unknown.

It was roughly calculated that the discharge of produced water at rates from 750-2000 m^3 d^{-1} (range with 1 or 2 platforms) would noticeably increase temperature and salinity in volumes of water ranging in dimensions from about 45 x 45 x 1 m to 120 x 120 x 1 m. The discharge of relatively warm produced water would also produce a small area of open water during the winter.

FIGURE 16-1

POTENTIAL EFFECTS OF DISCHARGES FROM PRODUCTION FIELDS AND OTHER FACILITIES ON ARCTIC CISCO AND BROAD WHITEFISH POPULATIONS

The construction of shorebases and development of shallow-water production fields will result in a decrease in the populations of arctic cisco and broad whitefish



Linkages

1. Warm water effluents and production water will be discharged into the freshwater area of the outer Mackenzie Delta.
2. Fish will be attracted to thermal plumes.
3. Contaminants in produced water in areas where fish are congregated will result in increased stress, reduced food availability and decreased fish growth.
4. Direct mortality due to effluents and decreased growth will reduce arctic cisco and broad whitefish populations.

Link 2: Fish will be attracted to thermal plumes.

Link 3: Contaminants in produced water in areas where fish are congregated will result in increased stress, reduce food availability and decreased growth.

A number of studies have shown that fish are attracted to thermal discharges and that fish can congregate in such areas (e.g., Ash et al. 1974; Gallaway and Strawn 1974). Attraction of some species of fish to areas receiving warm water discharges is expected to occur in the Beaufort Sea. However, given the small volumes of effluent that would be associated with the ADGO development and resultant small areas of nearshore habitat that would be affected, any impact of these discharges on fish was expected to be localized and not observable at the population level. It was suggested, however, that some individuals remaining in areas affected by production discharges could become tainted with hydrocarbons or accumulate heavy metals. These areas of potential concern are separately addressed in Hypothesis No. 13A and No. 13B, respectively.

CONCLUSION

The workshop subgroup concluded that impacts of production waste discharges from the ADGO field on populations of arctic cisco or broad whitefish were extremely unlikely due to the small volumes of effluent expected. Hypothesis No. 16 should be re-evaluated, however, if the estimated amounts of production water increase appreciably from present expectations. The following rationale was provided for this future review.

Fish migration patterns in the outer Mackenzie Delta are very poorly documented, and many individuals could pass through relatively small areas during the course of these migrations. There is also very limited information on overwintering areas where fish populations may be highly concentrated in the Delta. Although population-wide effects of production wastes are not anticipated, an unknown proportion of the individuals in these populations could be exposed to hydrocarbon production wastes in nearshore habitats. Effects on these individuals could include attraction to areas with warmer water, resultant increases in growth rates, disruption of normal movement patterns or mortality due to cold shock if thermal discharges are abruptly terminated.

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HYPOTHESIS NO. 17

WATER INTAKES WILL REDUCE POPULATIONS OF BROAD WHITEFISH AND ARCTIC CISCO

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INTRODUCTION

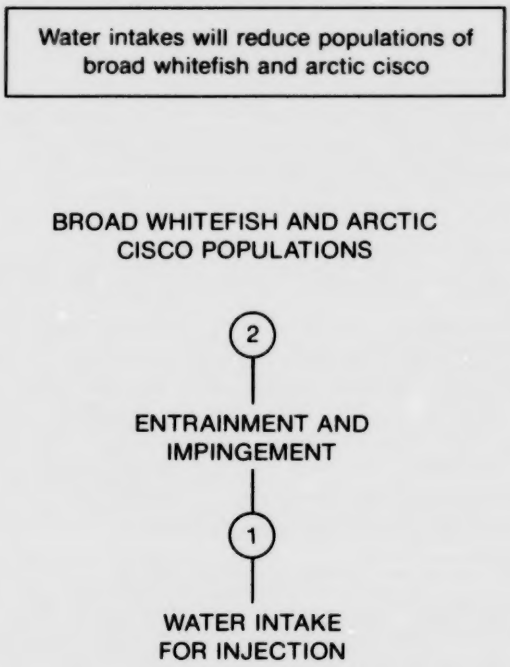
In the 1983-84 BEMP report, it was concluded that this hypothesis (Figure 17-1) was extremely unlikely and did not justify testing because: (1) the waterflood requirements in Canadian nearshore fields were expected to be a small fraction of those associated with the larger Alaskan nearshore fields, and (2) given even worst case assumptions, the losses of juvenile anadromous fish as a result of the Alaskan projects were expected to be small and inconsequential at the population level.

CONCLUSION

A review of this hypothesis during the present workshop led to the same conclusions and recommendations as those stated in the 1983-84 BEMP report. It was recommended that: (1) the results of the monitoring programs being conducted under the auspices of the U.S. Environmental Protection Agency, Army Corps of Engineers and National Marine Fisheries Service related to the Prudhoe Bay causeway be reviewed as they become available, and (2) if these results indicate that there may be potential concerns related to water intakes in the eastern Beaufort, then this hypothesis should be re-evaluated.

FIGURE 17-1

POTENTIAL EFFECTS OF WATER INTAKES ON BROAD WHITEFISH AND ARCTIC CISCO POPULATIONS


Water intakes will reduce populations of broad whitefish and arctic cisco
BROAD WHITEFISH AND ARCTIC CISCO POPULATIONS
2
ENTRAINMENT AND IMPINGEMENT
1
WATER INTAKE FOR INJECTION

Linkages

1. The intake of water for reservoir injection will cause entrainment and impingement of juvenile broad whitefish and arctic cisco.
2. The mortality associated with entrainment and impingement will reduce broad whitefish and arctic cisco populations.

HYPOTHESIS NO. 19

DREDGING AND DEPOSITION OF DREDGE SPOIL WILL REDUCE THE BEARDED SEAL POPULATION

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INTRODUCTION

This hypothesis and its associated linkages are illustrated in Figure 19-1. The working group completed a link-by-link review of the hypothesis, as well as any research relevant to each link that has been conducted since the last BEMP workshop. In addition, since Hypothesis No. 19 was prepared outside of the formal workshop during Phase I of BEMP, the current workshop is the first time that the linkages have been subjected to critical review by an interdisciplinary group.

ONGOING AND RECENT RESEARCH

The following ongoing and recent studies were identified by workshop participants as being potentially relevant to this hypothesis, although none were considered directly applicable to the overall hypothesis. Nevertheless, some of the information resulting from these studies was expected to be useful for evaluating certain aspects of the hypothesis linkages.

1. **Contaminant Body Burdens in Fish Along the Beaufort Sea Coast**

   This study is being conducted by the Freshwater Institute (DFO) and is directed primarily at determination of the background concentrations of hydrocarbons in key marine fish that inhabit coastal waters of the Beaufort Sea. To date, samples of fish harvested from eight arctic communities have been analysed for polycyclic aromatic hydrocarbons, polycyclic aromatic sulphur compounds, polychlorinated biphenyls and heavy metals. However, the results of these analyses are not yet available.

2. **Cadmium Uptake in Phytoplankton**

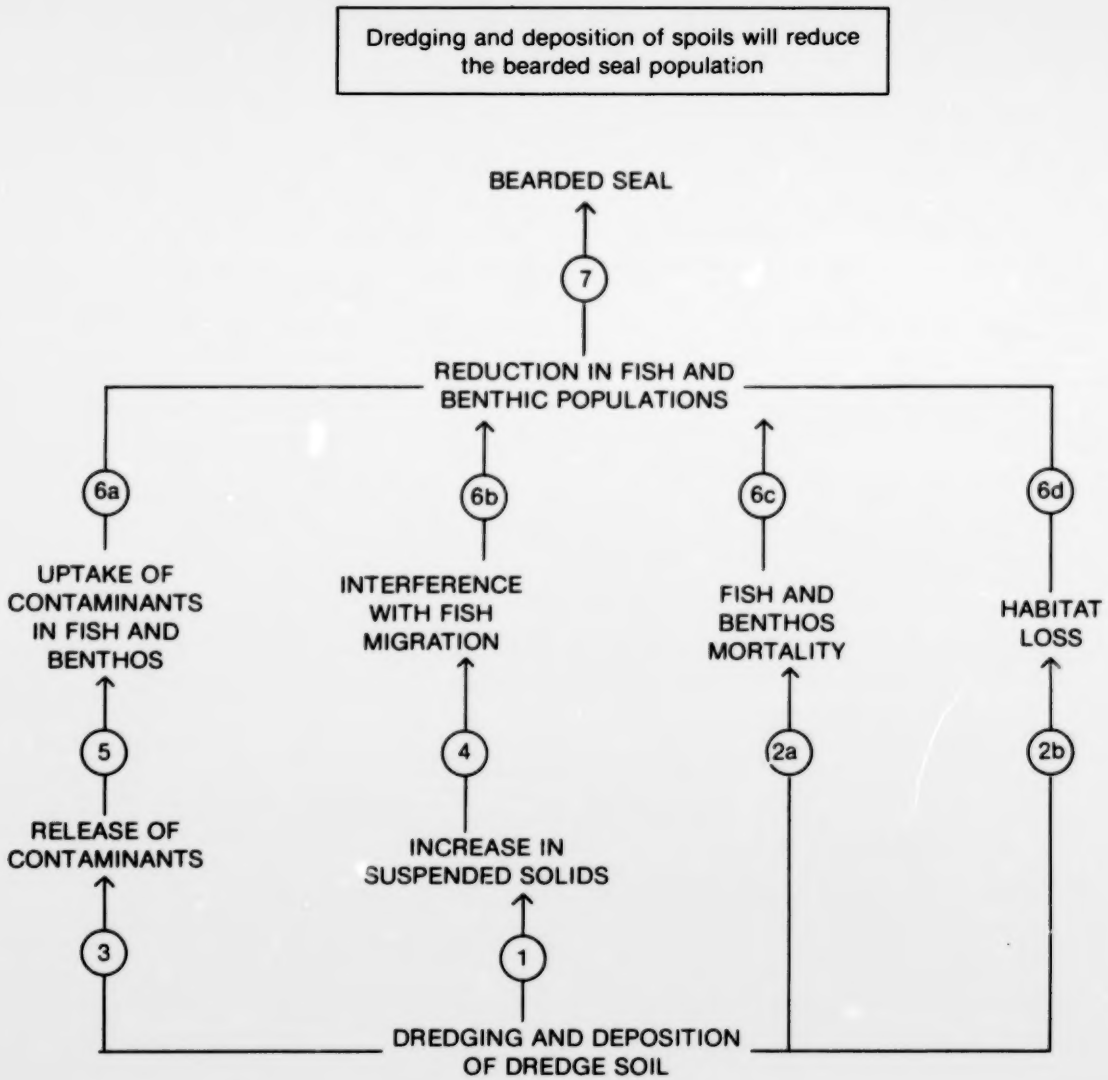
   This study is being conducted by the Environmental Protection Service (Yellowknife) in Tuktoyaktuk Harbour and the surrounding area and has two main objectives: (1) to compare the existing concentrations of cadmium in sediments and phytoplankton from the same area, and (2) to estimate the mobilization potential of cadmium from sediments. The research may provide some information relevant to the hypothesis link which suggests that dredging will release contaminants from the sediments (Link 3).

3. **Cadmium Uptake by Marine Mammals**

   Samples of marine mammal tissue (including bearded seals) collected on an opportunistic basis have been analysed for heavy metal content by the Department of Fisheries and Oceans, Winnipeg. However, this study is expected to be of only limited relevance to the present BEMP hypothesis.

FIGURE 19-1

POTENTIAL EFFECTS OF DREDGING AND DEPOSITION OF SPOILS ON THE BEARDED SEAL POPULATION



Linkages

1. Dredging and deposition of dredge spoils will increase concentrations of suspended solids in the water column.
2. Removal of seafloor material and its deposition in other areas will result in mortality of benthic invertebrates and fish and habitat loss.
3. Dredging will release contaminants from the sediments.
4. Increased suspended solids will interfere with fish migration.
5. Contaminants released during dredging will be taken up by fish and benthos.
6. Habitat loss, mortality, interference with migratory routes and uptake of contaminants will reduce fish and benthic invertebrate populations.
7. Reduced populations of prey (fish and benthos) will reduce the number of bearded seals.

4. "Priority Pollutant" Inventory in Beaufort Sea Sediments

This study was conducted by Arctic Laboratories Limited (1984) for the Environmental Protection Service (Yellowknife) and involved detailed organic anaylses of surficial sediments collected at abandoned artificial island sites in the Beaufort Sea.

5. Ocean Dumpsite Constraint Mapping/Selection

This study was conducted for the Environmental Protection Service (Yellowknife) and was completed in two phases:

1) Maps identifying areas of high and low constraints to ocean dumping were prepared using criteria such as biological resource utilization, fish and whale migration patterns, safety of transportation corridors and human activity (Dillon 1983).

2) Using the above constraint maps as a guide, criteria for the selection of ocean dumpsites for inert wastes were then developed (Thomas 1984).

6. Fish Feeding Ecology

During this DFO (Freshwater Institute) study, the distribution and abundance of major fish species in the Beaufort Sea will be mapped on an annual basis in relation to key environmental parameters. The research includes: (1) analysis of fish stomach contents, (2) description of fish feeding habitats, and (3) collection of data in open water and under ice habitats to determine the critical factors influencing the allocation of fish prey organisms.

7. Nearshore Benthic Ecology

Physical and chemical analyses of nearshore sediments are being used by the Environmental Protection Service (Yellowknife) to determine the factors influencing the abundance of various macrofauna species.

Of the research programs listed above, only Studies 4 and 5 are complete. The results of the remaining investigations will not be available for 1 to 5 years.

It was also noted that a great deal of information on the environmental effects of dredging is available for other geographical areas of the world (e.g., Morton 1977, Hirsch et al. 1978; Murden 1984). Some of this information will be relevant to dredging operations in the Beaufort Sea and is discussed below.

REVIEW OF LINKAGES AND RELEVANT RESEARCH

Link 1: Dredging and deposition of dredge spoil will increase concentrations of suspended solids in the water column.

This link was considered valid since both dredging and deposition of dredge spoil have been shown to increase suspended solid concentrations beyond normal background levels (e.g., Khan and Grossi 1984; Thomas et al. 1985). However, increased turbidity is usually confined to an area within approximately 500 metres of dredging activities (Lunz et al. 1984) and only persists for brief periods (Barnard 1978). In most shallow ($<$5m) areas along the Beaufort Sea coast, natural processes such as breaking waves and sediment input from the Mackenzie River combine to produce highly turbid nearshore waters. Such conditions would tend to mask the sediment resuspension associated wtih dredging operations. In the offshore ($>$5m), increased turbidity resulting from dredging and disposal activities would also be short-term and affect only a very small proportion of the receiving environment.

Link 3: Dredging will release contaminants from the sediments.

Although some release of contaminants occurs during most dredging and disposal operations (Thomas et al. 1985), the amounts of contaminants released are generally inconsequential. In the case of contaminated sediments, much larger quantities of specific elements or compounds can be released. After numerous investigations of the effects of disposed dredge material, the U.S. Army Corps of Engineers concluded that:

1) No significant long-term increases in contaminant concentrations in the water column have been observed at any aquatic disposal sites in U.S. waters (Brannon 1978).

2) The magnitude of release of various contaminants to the water column has been found to be correlated poorly or not at all with physical and chemical characteristics of dredge spoils (Jones and Lee 1978).

Link 5: Contaminants released during dredging will be taken up by fish and benthos.

Uptake by fish and benthos of contaminants released from dredged materials is possible, but usually very limited. Hirsch et al. (1978) report that the release of heavy metals from resuspended sediments during dredging and disposal, their uptake into tissues of organisms, and the accumulation of oil and grease residues by organisms have been rare. Furthermore, an overview of the recent literature on dredging indicates that while there is evidence that contaminants can enter food chains from sediments (Thomas et al. 1985), there are no clear case studies completed to date which indicate that even contaminated dredged material has resulted in a measureable impact on the food chain (Kester et al. 1983). The potential for direct uptake of released contaminants by benthic organisms is considered much greater than by fish due to their closer association with sediments.

Link 6a: Uptake of contaminants will reduce fish and benthic invertebrate populations.

This link was judged to be highly unlikely. It was considered possible that a limited number of individual benthic invertebrates or fish could accumulate contaminants to concentrations significantly above background, but it is unreasonable to expect that this could lead to measureable reductions in populations of fish or benthic invertebrates.

Link 7: Reduced populations of prey (fish and benthos) will reduce the number of bearded seals.

This link was considered exceedingly remote because Link 6 was unlikely.

Link 4: Increased suspended solids will interfere with fish migration.

Link 4 is also considered highly unlikely. The portion of the water column affected by a dredge plume would be small compared to adjacent unaffected areas. In addition, frequent natural events occur in the nearshore Beaufort Sea which cause increases in turbidity as large or larger than those associated with dredging activities.

Link 6b: Interference with migratory routes due to increased suspended solids will reduce fish populations.

Link 7: Reduced populations of prey (fish and benthos) will reduce the number of bearded seals.

These links are highly unlikely due to the low probability of Link 4. It was also suggested that bearded seals may not feed at times in the open water season when they are likely to occur in nearshore dredging areas, thereby limiting the potential for significant bioaccumulation of contaminants. Furthermore, a decrease in the size of the bearded seal *population* is remote, given the scale of possible reductions in fish and benthic populations that could result from dredging operations in the Beaufort Sea. However, sublethal effects of dredging on individual seals are considered possible.

Link 2a: Removal of seafloor material and its deposition in other areas will result in mortality of benthic invertebrates and fish.

Available information indicates that some mortality of benthic invertebrates (primarily infauna) and, to a lesser extent, fish will occur during dredging and disposal operations. Mortality is largely due to physical damage caused by the dredge head and smothering from rapid sedimentation of solids at both dredging and disposal sites. However, the number of organisms affected would be small and limited to the areas of direct physical disturbance. It was emphasized that mortality of fish and benthos could be significant if a unique population of fish or benthic fauna was destroyed by a dredging operation. However, such populations are not known to exist in the Beaufort Sea.

Link 6c: Mortality of fish and benthos will result in population-wide reductions in abundance.

Any reductions in fish or benthic invertebrate populations will be restricted to the direct localized loss of individuals during dredging and dredge spoil disposal. Population-wide effects on fish or benthos are not anticipated because of the relatively small areas affected by dredging operations. Therefore, Link 7 was also considered extremely unlikely.

Link 2b: Removal of seafloor material and its deposition in other areas will result in habitat loss for benthic invertebrates and fish.

As with fish and benthos mortality, loss of benthic habitat is a well documented direct consequence of dredging and dredge spoil disposal operations (Thomas et al. 1985). Habitat creation also occurs in some instances (e.g., construction of artificial islands), and this may have beneficial effects on both fish and benthic fauna.

Link 6d: Loss of habitat will reduce population of fish and benthic fauna.

It is expected that habitat loss would be limited to areas of physical disturbance associated with dredging operations. Since these areas are a small proportion of the available habitat in the Beaufort Sea, the losses of benthos and fish would be equally small. Effects of habitat loss on populations of fish and benthos are highly unlikely, as would be any indirect effects of these losses on the population of bearded seals.

CONCLUSION

Following a review of the validity of each linkage, the workshop group concluded that, on the basis of worldwide experience regarding the effects of dredging operations and the anticipated intensity and locations of dredging required in the Beaufort Sea, this hypothesis was unlikely and does not justify testing.

RESEARCH AND MONITORING

No research or monitoring was recommended for this hypothesis because it was concluded that at the estimated levels of dredging identified in the Beaufort hydrocarbon development scenario, no reasonable argument for a reduction in the population of bearded seals could be developed. However, it was stated that bioaccumulation of some contaminants (particularly heavy metals) could occur in the livers of individual bearded seals if they fed in areas of active dredging for extended periods. Consequently, measurement of the heavy metal content in bearded seal livers was recommended on an opportunistic basis because of the possible link to human health. It was also noted that application of mitigative measures and general knowledge of the bearded seal activity areas would be important to the management of dredging projects. For example, dredging could be avoided in known areas of sensitive or unique habitat.

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HYPOTHESIS NO. 20

THE DISCHARGE OF CUTTINGS CONTAMINATED WITH OIL-BASE DRILLING MUDS DURING DEVELOPMENT OF SHALLOW-WATER PRODUCTION FACILITIES WILL REDUCE POPULATIONS OF ARCTIC CISCO, BROAD WHITEFISH AND LAKE WHITEFISH, AND WILL ALSO DECREASE THE HARVEST OF THESE SPECIES DUE TO HYDROCARBON ACCUMULATION (TAINTING)

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INTRODUCTION

Potential changes in the hydrocarbon development scenario for the Beaufort Sea were described during the opening plenary session of the 1985 BEMP workshop. One of two changes in the scenario since the last workshop is the possible use of oil-base drilling fluids for delineation and development drilling. Although there were no firm plans by the petroleum industry to employ these drilling mud formulations in the near future, their use has been approved by the Canada Oil and Gas Lands Administration (COGLA) for certain drilling applications on the east coast of Canada (i.e., Alma F-67, South Desbarres 0-76 and West Venture C-62). Consequently, it was considered possible that approvals may eventually be granted for their use in the Beaufort Sea. (Editor's Note: Since the February 1985 BEMP workshop, Esso Resources Canada has applied for an approval to use oil-base drilling muds for exploratory drilling in their Beaufort operations). It was also assumed that marine disposal of oil-base muds *per se* may be prohibited by regulatory agencies, but that discharge of drilling cuttings would be permitted following treatment to remove and recover much of the associated oil-base drilling fluids.

The rinsing of cuttings does not remove all of the adhering drilling mud, and therefore the discharge of cuttings will introduce some amount of petroleum hydrocarbons to the marine environments. Based on information provided in Thomas et al. (1983), up to 25 percent (wt/wt) of the mud-cuttings mixture may be petroleum hydrocarbons derived from oil-base drilling fluids for untreated diesel cuttings, 15 percent for treated diesel cutings and 5-10 percent for untreated paraffin cuttings.

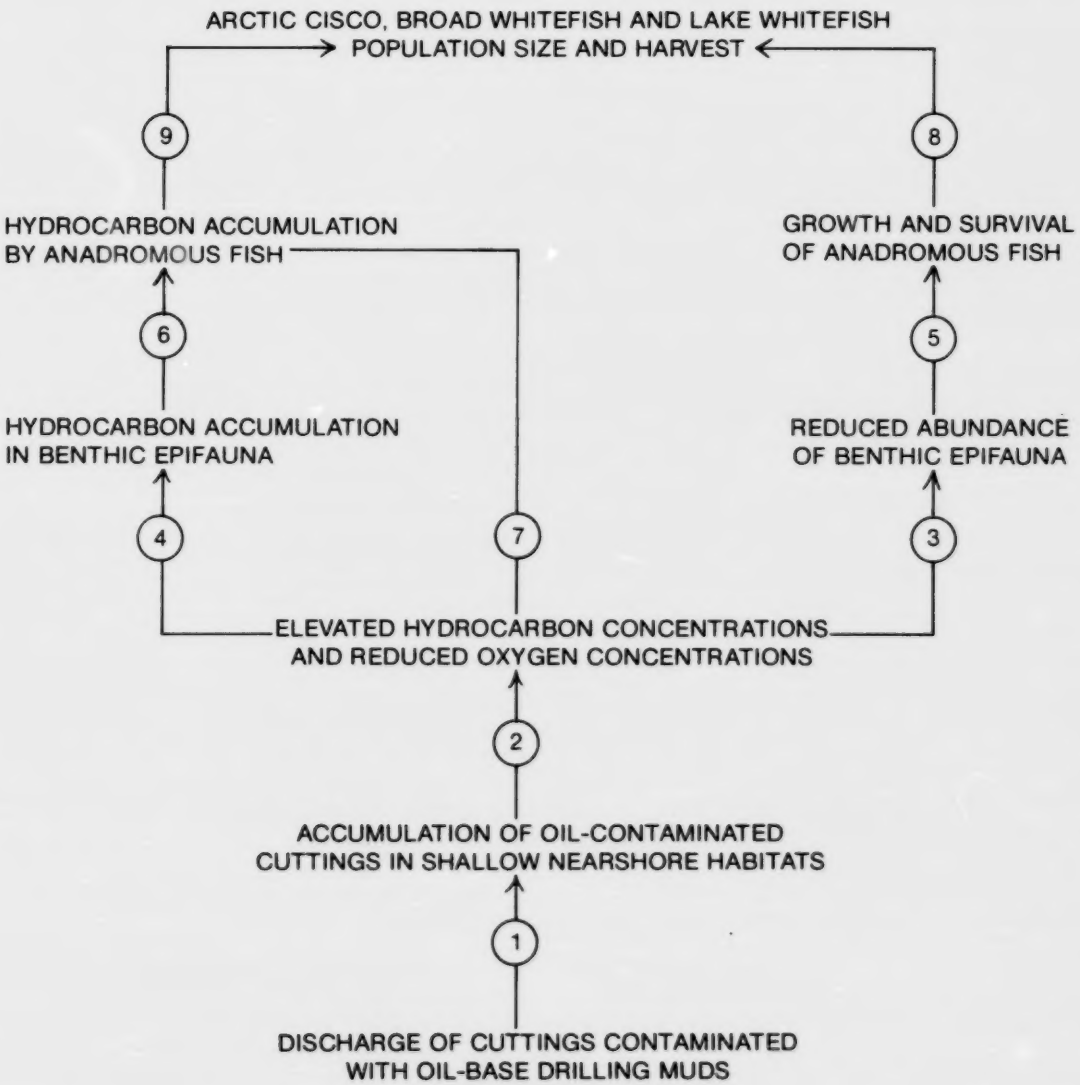
In response to this potential change in the development scenario, it was agreed that a new hypothesis should be formulated and evaluated at the present workshop. Accordingly, a preliminary hypothesis and statement of its associated linkages were prepared prior to the meeting of this working group. At the onset of the discussions, it was suggested that two hypotheses related to discharge of cuttings contaminated with oil-base drilling muds could be evaluated. The first would focus on relatively shallow (< 20m) coastal areas and have anadromous fishes as its VEC, while the second would deal with discharges from deeper (>20m) offshore production facilities. The group concluded that the hypothesis for the offshore case was invalid because: (1) anadromous fishes are rarely found offshore, and (2) bowhead whales (the only other possible VEC) would not be expected to obtain significant quantities of oil-contaminated food from the relatively small cuttings piles.

Although the group believed that it was highly unlikely that regulatory agencies would permit the discharge of drill cuttings contaminated with oil-base muds in the nearshore zone, it was considered important to examine the hypothesis independent of future regulatory policy. In addition, no distinction was made during the discussion between the possible types of oil-base muds (e.g., diesel, low-toxicity mineral base, etc.) that could be employed in drilling operations. In order to focus discussions, however, the ADGO well was assumed to be a typical nearshore site where oil-contaminated cuttings might be discharged.

FIGURE 20-1

EFFECTS OF CUTTINGS CONTAMINATED WITH OIL-BASE DRILLING MUDS ON POPULATIONS AND HARVEST OF ARCTIC CISCO, BROAD WHITEFISH AND LAKE WHITEFISH

The discharge of cuttings contaminated with oil-base drilling muds during development of shallow-water production facilities will reduce populations of arctic cisco, broad whitefish and lake whitefish, and will also decrease the harvest of these species due to hydrocarbon accumulation (tainting)



Linkages

1. Cuttings contaminated with oil-base drilling muds and discharged during delineation or development drilling will rapidly settle to the seafloor, and resist subsequent dispersion due to the cohesiveness of mud-cuttings mixtures.
2. In areas of cuttings accumulation, elevated hydrocarbon concentrations and reduced oxygen levels will occur during the slow degradation of oil-base muds.
3. Seasonal abundance of benthic epifauna will be reduced in areas of mud-cuttings accumulation due to oxygen depletion and toxicity of petroleum hydrocarbons in drilling muds or the products resulting from their degradation.
4. Benthic epifauna remaining in habitats containing drilling mud-cuttings mixtures will accumulate petroleum hydrocarbons.
5. Decreased abundance of benthic epifauna will affect the growth and survival of rearing and migratory populations of arctic cisco, broad whitefish and lake whitefish in nearshore waters.
6. Arctic cisco, broad whitefish and lake whitefish will accumulate petroleum hydrocarbons from ingestion of contaminated prey organisms.
7. Arctic cisco, broad whitefish and lake whitefish remaining in areas containing oil-contaminated cuttings will directly accumulate petroleum hydrocarbons.
8. The size of arctic cisco, broad whitefish and lake whitefish populations will be decreased due to local effects of reduced prey availability on growth and survival.
9. The harvest of arctic cisco, broad whitefish and lake whitefish populations will be reduced due to tainting by petroleum hydrocarbons or the perception that tainting has occurred.

The hypothesis presented to the working group originally had arctic cisco and broad whitefish as its VECs, but was subsequently expanded to include lake whitefish (Figure 20-1). The following sections summarize: (1) ongoing research that may be relevant to this hypothesis, (2) the probable validity of each of its links, and (3) the overall conclusions and recommendations of the group for research and monitoring to address the hypothesis.

ONGOING STUDIES

Since this is a new BEMP hypothesis, its proposed linkages had not been previously examined by the workshop participants, nor had research been recommended to examine the validity of these linkages. In addition, project overviews of relevant research had not been prepared and reviewed by participants before the workshop. Nevertheless, three ongoing research projects were briefly examined during the discussion of this hypothesis.

1. **Estimation of oxygen depletion by oil-base muds in arctic marine waters.**

   This INAC-funded laboratory study is being conducted by Atlantic Oceanics Company Ltd. and is designed to determine the oxygen demand of low toxicity mud-cuttings mixtures, as well as the possible solubilization of metals in a number of sediments collected from the Beaufort Sea. The expected completion date for the study is August, 1985.

2. **Oil cuttings dispersion plume modelling**

   The object of this study is to test an existing drilling discharge plume dispersion model at Shell Alma F-67, Shell South Desbarres 0-76 and Mobil West Venture C-62 on the Scotian Shelf, where low toxicity oil-base muds are being used or are proposed for use on an experimental basis. The program also includes limited biological sampling. This study is being conducted for ESRF by Dobrocky Seatech Ltd. and is scheduled for completion in July 1985.

3. **Fish tainting by hydrocarbons**

   The objectives of this ESRF study are to evaluate the real or perceived concerns associated with fish and shellfish tainting due to oil spills and hydrocarbon development activities, and to assess the various approaches and procedures to detect tainting (see Appendix A, Project Overview No. 22).

REVIEW OF LINKAGES

Link 1: Cuttings contaminated with oil-base drilling muds and discharged during delineation or development drilling will rapidly settle to the seafloor, and resist subsequent dispersion due to the cohesiveness of mud-cuttings mixtures.

Based on information from the North Sea (United Kingdom Offshore Operators Association et al. 1983), discharged oily cuttings are usually cohesive and resist dispersion in the marine environment once they reach the seabed. Although high wave energies occur in the Beaufort Sea during the open water season and ice action can be an effective force for abrading and displacing sediments in the spring, the group agreed that the cohesion of oiled cuttings was sufficient to resist dispersal by these forces. However, it was expected that erosion would likely spread the cuttings within an area of several hundred metres from piles on the seafloor. It was therefore concluded that this hypothesis link is valid.

Link 2: In areas of cuttings accumulation, elevated hydrocarbon concentations and reduced oxygen levels will occur during the slow degradation of oil-base muds.

Information collected during offshore studies in the North Sea indicates that this link is also valid. Most of the oil discharged with cuttings is either strongly bound to the surface of the cuttings themselves or to benthic sediments. Consequently, the highest hydrocarbon concentrations tend to be found within cuttings piles or in underlying sediments, but may also be relatively high in the water just above these piles (Thomas et al. 1983; UKOAA et al. 1983).

The aerobic degradation of petroleum hydrocarbons by micro-organisms creates an oxygen demand. Research conducted by C. Johnson and coworkers at the Institute of Offshore Engineering, Heriot-Watt University (Edinburgh) indicates that this oxygen demand is highest within the cuttings piles themselves, and results in very low oxygen levels or completely anaerobic conditions (Thomas et al. 1983; UKOAA et al. 1983). However, oxygen depletion within cuttings piles is not an environmental concern since, with the exception of oleophilic micro-organisms, they are completely devoid of biota, and any reduced oxygen levels in overlying waters is restricted to areas within a few centimetres of oil-contaminated cuttings.

Link 3: Seasonal abundance of benthic epifauna will be reduced in areas of mud-cuttings accumulation due to oxygen depletion and toxicity of petroleum hydrocarbons in drilling muds or the products resulting from their degradation.

The discharge of oil-contaminated cuttings would have more pronounced effects on benthic infauna than epifauna, although less mobile and sedentary epifauna could also be affected to some degree. The main cause of decreases in the abundance of epifauna will be smothering by the cuttings, and to a lesser extent, the toxic effects of petroleum hydrocarbons and low oxygen levels. Both smothering and toxicity will be limited to the area directly under the cuttings pile. It was agreed that the loss of benthic epifauna would be very limited because a cuttings pile will be a local disruption to benthic habitat. For example, the average volume of cuttings produced for a single well in the Beaufort Sea has been estimated at 300m^3 (Thomas et al. 1983). Assuming 20 wells per production "platform", the total volume of cuttings discharged from a particular point source would be 6000 m^3. This volume of cuttings would cover an area of seabed approximately 50 m x 50 m to a depth of 2.5 m (which is the water depth at ADGO).

Link 4: Benthic epifauna remaining in habitats containing drilling mud-cuttings mixtures will accumulate petroleum hydrocarbons.

Petroleum hydrocarbons will be taken up by benthic invertebrates to variable extents, depending on the species and specific hydrocarbons present in the oil (Blackman 1983). This link is therefore considered valid.

Link 5: Decreased abundance of benthic epifauna will affect the growth and survival of rearing and migratory populations of arctic cisco, broad whitefish and lake whitefish in nearshore waters.

Link 8: The size of arctic cisco, broad whitefish and lake whitefish populations will be decreased due to local effects of reduced prey availability on growth and survival.

These links were judged to be invalid because the local losses of benthic organisms on the scale described above would not have significant effects on the growth and survival of rearing and migrating populations of arctic cisco, broad whitefish and lake whitefish in nearshore waters.

Link 6: Arctic cisco, broad whitefish and lake whitefish will accumulate petroleum hydrocarbons from ingestion of contaminated prey organisms.

This link was considered possible, but the extent to which hydrocarbons accumulate in individuals of these species would depend on their feeding habits and the amount of benthic biomass available. The group concluded that for the following two reasons, only limited uptake of hydrocarbons would be likely:

1. The available biomass of epibenthic invertebrate food organisms in this nearshore zone will be low. Using a worst case argument, the maximum biomass of epifauna on a cuttings pile located within the estuarine zone of the Beaufort Sea (to approximately the 15 m isobath) would be about 5 g m^{-2} (Wacasey 1975), if it is assumed that colonization of the cuttings piles occurs to the same degree as in the adjacent habitat. For the maximum cuttings discharge per field (6000 m^3 for 20 wells; Thomas et al. 1983) and a cutting pile surface area of 2500 m^2 (50 m x 50 m), the total biomass of epifauna that would be available for consumption by fish would be only 12.5 kg.
2. Broad whitefish, lake whitefish and arctic cisco spend only part of the year in nearshore waters of the Beaufort Sea. Furthermore, it is suspected that these populations are not actively feeding during this period (Bond 1982; Lawrence et al. 1984; Bond and Erickson 1985).

Link 7: Arctic cisco, broad whitefish and lake whitefish remaining in areas containing oil-contaminated cuttings will directly accumulate petroleum hydrocarbons.

The group considered this link extremely improbable since direct uptake of hydrocarbons from sediments by fish has not been clearly demonstrated to date (Duval et al. 1985).

Link 9: The harvest of arctic cisco, broad whitefish and lake whitefish populations will be reduced due to tainting by petroleum hydrocarbons or the perception that tainting has occurred.

There is substantial evidence to indicate that this link is valid. However, the group recognized that the potential for hydrocarbons to taint individuals from these populations was low due to the limited area affected by oil-contaminated cuttings and the low biomass of prey that could accumulate petroleum hydrocarbons. Nevertheless, tainting of even a small number of fish is highly visible to society and therefore considered undesirable.

CONCLUSION

The hypothesis encompassed by Links 1, 2, 4, 6 and 9 was considered both valid and testable from a site-specific perspective. However, it was concluded that the effects of oil-contaminated cuttings on regional populations of arctic cisco, broad whitefish and lake whitefish would likely be insignificant.

The portion of this hypothesis involving Links 1, 2, 3, 5 and 8 was expected to be highly improbable and would not justify testing through a monitoring program.

RESEARCH AND MONITORING

In the absence of a site-specific case upon which to test the conclusion outlined above, no research or monitoring was recommended in relation to this new hypothesis. However, it was concluded that the results of the ongoing ESRF tainting study should be reviewed when available to determine if they would affect any of the conclusions of the present group.

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APPENDIX A

1984-85 PROJECT OVERVIEWS

BEMP PROJECT OVERVIEW NO. 1

TITLE:	1984 Beaufort Sea Bowhead Whale Monitoring Study
PRINCIPAL INVESTIGATORS:	Lois Harwood, G.A. Borstad
AFFILIATION:	ESL Environmental Sciences Limited, Sidney, B.C. G.A. Borstad Ltd., Sidney, B.C.
FUNDING SOURCE:	Environmental Studies Revolving Funds (ESRF) and DIAND (NOGAP)
EXPECTED COMPLETION DATE:	January-February 1985
RELEVANT BEMP HYPOTHESIS NUMBER(S):	1

BRIEF PROJECT DESCRIPTION

The purpose of this study was to determine the relative abundance and distribution of bowhead whales in the southeastern Beaufort Sea during the last half of August and first half of September 1984, and was the fifth consecutive year of systematic aerial surveys of bowheads on their summer range. The survey area extended from 141°W longitude (Yukon-Alaska border) to 127°22'W longitude (35 km east of Cape Bathurst), and from the 2 m isobath seaward to 25 km beyond the 100 m isobath (except between 141°W and 138°W longitude where the seaward limit of the survey area was 70°20'N latitude). However, a program separately funded by INAC (NOGAP) extended the survey region from the northern boundary of the ESRF study area to the 7-9/10 concentration edge of the pack ice and the eastern boundary to 125°47'W longitude (western portion of Franklin Bay). The methods followed during this study were consistent with those employed during industry-sponsored programs conducted from 1980 to 1983, and included a minimum of 10 percent survey coverage throughout the study area and observations of other marine mammals present in the region.

The 1984 bowhead whale program also included a coincident satellite imagery component to allow comparison of bowhead distribution patterns with oceanographic features (sea surface temperature and water colour) depicted in imagery. The satellite data were relayed on a near real-time basis to the field crew in Inuvik.

The final report will describe the distribution and abundance of bowhead whales in the southeast Beaufort Sea in relation to water depths, ice type and concentration, surface water temperature and turbidity. The distribution of whales in relation to concurrent oil industry activities in the region will also be examined, while spatial distribution patterns noted in 1984 will be compared with trends observed during the previous four years of systematic aerial surveys. Bowhead whale data collected during four systematic white whale surveys conducted in the offshore Beaufort during July - early August 1984 (see Project Overview No. 7), as well as incidental observations of marine mammals by industry personnel, will also be analysed and discussed in the final report for this project.

The distribution of bowhead whales varied throughout the open water season in 1984, and as in past years, bowheads were concentrated in specific areas (particularly in Franklin Bay, close to the Yukon Coast and along the western edge of the Mackenzie plume). Like 1982 and 1983, few whales were recorded in the industrial zone compared to distributions observed in 1980 and 1981.

The results of the satellite oceanography component of the study indicated that the large numbers of bowheads along the Yukon coast, observed in September 1984, coincided with oceanographic features

that suggested the occurrence of upwelling. A similar situation was observed in August 1984, following a prolonged period of easterly winds (Borstad 1984 - Project Overview No. 33). It was also noted that ice strings (long filaments of brash ice aggregated in convergences or current shears) are a recognizable feature that may be relevant to bowhead distribution. Not all thermal fronts depicted in satellite imagery had associated whale sightings, nor were all whales observed during the surveys found in areas with visible fronts.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

Hypothesis No. 1, described and evaluated during the first year of BEMP, stated that *"Ship traffic, seismic exploration and active offshore structures will cause a reduction in the western Arctic population of bowhead whales"*. Continued annual systematic surveys of bowhead distribution and relative abundance were one of several recommendations made in relation to this hypothesis. Although information collected during the course of these surveys will *not* directly allow testing of the above impact hypothesis, it will provide indirect evidence relevant to specific hypothesis linkages suggesting that stationary (Link 1) and mobile (Link 2) sources of industry activity will lead to exclusion of bowhead whales (Figure 1-1; main report). In addition, data collected during the past, present and future systematic bowhead whale surveys will provide some of the information necessary to distinguish potential effects of petroleum industry operations from changes in distribution patterns associated with natural factors. For example, the 1983-84 BEMP Final Report suggested that variations in bowhead distribution observed during the four summers since 1980 may be related to variations in food (zooplankton) distribution and availability, which are in turn influenced by both regional and local oceanographic phenonema. The project is therefore relevant to BEMP because it will provide information on natural factors (ice, water depth and the location of oceanographic fronts) that may directly and indirectly influence the distribution of bowhead whales in the region. This research program is also considered necessary to form the basis for the design of future monitoring programs that will analyse cause-effect relationships and thereby test the above impact hypothesis.

BEMP PROJECT OVERVIEW NO. 2

TITLE:	Factors Determining Bowhead Whale Distribution in the Beaufort Sea: A Feasibility Study
PRINCIPAL INVESTIGATORS:	Rolph Davis, David Fissel and Gary Borstad
AFFILIATION:	LGL Limited, King City, Ontario Arctic Sciences Ltd., Sidney, B.C. G.A. Borstad Ltd., Sidney, B.C.
FUNDING SOURCE:	Environmental Studies Revolving Funds (ESRF)
EXPECTED COMPLETION DATE:	June 1985
RELEVANT BEMP HYPOTHESIS NUMBER(S):	1

BRIEF PROJECT DESCRIPTION

Between 1980 and 1983, systematic aerial surveys of the distribution of bowhead whales over their summer range were conducted in the southeastern Beaufort Sea. During this four year period, there has been fewer animals occurring in the zone where activities of the petroleum industry have been concentrated.

Two interrelated hypotheses were advanced during Phase I of BEMP to explain the differences in bowhead whale distribution in the period from 1980 and 1983. These were:

1. Bowheads will avoid the industrial zone because of noise and disturbance in this region of the Beaufort Sea; and
2. Bowhead distribution is determined by the locations of available food (areas containing relatively high zooplankton densities).

On the latter point, the distribution of zooplankton patches is expected to be related to oceanographic and meteorological factors.

The objective of the Feasibility Study was to evaluate the feasibility of using simply (and inexpensively) measured environmental data (i.e., wind, surface distribution of sea temperature and turbidity obtained from satellite imagery) to predict bowhead distributions. To meet this objective the available environmental data from 1980-83 were examined to determine the locations of potential zooplankton concentrating mechanisms (as indicated by surface oceanographic features). These data were compared with bowhead distributions within the same period to determine whether or not the distributions of bowheads are correlated with environmental data.

Wind and Mackenzie River discharge data for the months of July, August and September in 1980-1983 were collected and grouped into periods that defined specific wind events. All available satellite imagery for these periods was analysed, using both the visible and thermal bands to map locations of the boundaries of the Mackenzie River plume. Available data on bowhead whale distributions were also mapped by wind event periods.

The final report will contain recommendations for the design of a field research program to test the specific hypotheses concerning the distribution of bowhead whales in relation to physical phenomena and zooplankton. Although this report will not be complete until June 1985, preliminary results of the analyses were available at the time of the BEMP workshop in early February. These are summarized below.

Analysis of the small amount of zooplankton data that has been collected in the eastern Beaufort indicated that zooplankton standing stock was positively correlated with salinity. This suggests that

areas covered by the concentrated low salinity portions of the Mackenzie River plume may support low densities of zooplankton, and therefore would not be suitable feeding habitats for bowhead whales. The area where industry activities have been focused lies within a transition zone that, depending on the winds, may or may not be under the influence of this concentrated plume. During periods when the wind is from the west, the plume tends to be situated along the shore of the Tuktoyaktuk Peninsula and Richards Island. During easterly winds, the majority of the industrial zone north and west of Richards Island would be more greatly influenced by estuarine water.

During 1980, bowhead whales were found off Richards Island during the first part of August, and the highest densities of whales were observed to the northeast during successive weeks. An estuarine front was also transported successively to the northeast throughout this period, and the locations of bowheads closely corresponded to the locations of these fronts.

In 1981, bowhead whales were not found in the industrial zone until the latter part of August. During the first part of August, this area was characterized by a surface layer of low salinity water, and the subsequent appearance of whales was accompanied by an increase in salinity. In contrast, the salinity was high in the industrial zone throughout the 1980 open water season.

Whales were not abundant in the industrial zone in 1982 and 1983. A comparison of wind regimes, temperature data and satellite imagery with the presence or absence of whales in this zone suggests the following:

1. There are periods in 1982 and 1983 when whales would have been expected to be present on the basis of the 1980 and 1981 wind and oceanographic conditions and the concurrent presence of large numbers of whales;
2. The presence of whales was associated with a strong northerly component to the wind; and
3. The absence of whales was associated with a lack of this northerly wind component.

Preliminary results of this research program suggest that the presence of bowhead whales in the industrial zone is associated with the presence of high salinity waters and, on some occasions, the presence of estuarine fronts. However the reverse may not be true.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

Hypothesis No. 1 states that *"Ship traffic, seismic exploration and active offshore structures will cause a reduction in the western Arctic population of bowhead whales"*. This ESRF-funded study is examining an interrelated hypothesis: bowhead whale distribution patterns are related to oceanographic factors which influence the distribution of the food supply of this population. The research program is relevant to BEMP because it will provide information on oceanographic factors that may directly and indirectly influence the distribution of bowhead whales. The validity of Hypothesis No. 1 would be significantly reduced if evidence in support of this interrelated hypothesis emerges from the Bowhead Whale Feasibility Study and/or subsequent field research programs.

BEMP PROJECT OVERVIEW NO. 3

TITLE:	The Long-Term Effects of Offshore Industrial Activities
PRINCIPAL INVESTIGATOR:	Rolph Davis
AFFILIATION:	LGL Limited, King City, Ontario
FUNDING SOURCE:	DSS, NOGAP (DIAND and DFO)
EXPECTED COMPLETION DATE:	May 1985
RELEVANT BEMP HYPOTHESIS NUMBER(S):	1

BRIEF PROJECT DESCRIPTION

The purpose of this study is to test the application of a photographic identification technique to the examination of medium- and long-term responses of bowhead whales to offshore industrial development. A photographic method for identifying recognizable bowheads has proven effective in that resightings of specific individuals has been documented. In this study, the technique is being used to document the occurrence and duration of stay of bowhead whales near industrial sites and elsewhere in the southeastern Beaufort Sea.

The study area included the offshore hydrocarbon exploration areas of the Mackenzie Delta and Tuktoyaktuk Peninsula, and extended west to Herschel Island and east to Franklin Bay. Within this region, areas of most intensive study were determined by the concentrations of whales.

Emphasis was placed on repeated searches to determine whether recognizable individuals were resighted at similar rates in areas of industrial activity and in unaffected control areas. Although results obtained during the 1984 open water season will be discussed in greatest detail, data on identifiable whales obtained in 1981-83 studies (LGL, NMFS) will allow some determination of year to year recurrence rates. The photographic technique also permits determination of the size and stature (i.e., calf, yearling, immature, mature) of individual whales, and should indicate whether or not the whales occurring near industrial activities are a random segment of the population. The research also involved detailed observation of bowhead behaviour patterns.

The study was co-ordinated with LGL's ongoing study (MMS, U.S. Government) of the short-term behavioural reactions of bowhead whales to industrial activities.

Only preliminary results were available for the 1985 BEMP workshop. The principal findings relevant to Hypothesis No. 1 are summarized below.

1. The numbers of bowheads found in the offshore industrial zone during August and early September 1984 were somewhat greater than in 1982 and 1983, but were still substantially lower than numbers observed in 1980 and 1981.
2. Congregations of whales that persisted along the Yukon Coast and along the plume edge northeast of Shingle Point consisted primarily of small animals. These bowheads were exposed to varying degrees of industry-related noise and disturbance. A few larger animals were occasionally present in these areas, but were only briefly observed and apparently did not remain in the zone. From this and previous photogrammetric studies of bowhead whale size/frequency, the authors concluded that the small animals referred to above were probably yearlings, while the larger animals were adults and near-adults.
3. Most bowheads in the southern part of the main industrial zone off the Mackenzie Delta were also small. Information on residence times also suggests that these animals moved through the area relatively quickly.
4. Large animals which were probably adults and sub-adults were found primarily outside the industrial zone both to the north of and within Franklin Bay.

These findings indicate that for the third consecutive year, relatively few bowheads were present in the industrial zone. Those individuals that were present were mostly small young animals. The older component of the population apparently did not occur in the development zone.

As evident in some other whale species, this trend may be the result of differential feeding and/or habitat requirements of various age (and/or sex) classes of the population. The author raised the concern, however, that since there is presumably a relationship between age (as estimated from size) and experience, the apparent differential distribution could indicate that there is a general learned avoidance of the industrial zone by bowhead whales.

The results of this research will, therefore, be examined in relation to the hypothesis link that bowhead whales will be excluded from the zone of industrial activity.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

Hypothesis No. 1 states that *"Ship traffic, seismic exploration and active offshore structures will cause a reduction in the western Arctic population of bowhead whales"*. More specifically, active drilling or production islands have associated ship and helicopter traffic, and these mobile noise sources could act in conjunction with on-island activities to produce a zone of at least partial exclusion of whales around offshore islands and platforms.

During 1980 and to a lesser extent 1981, large numbers of bowheads occurred within the industrial zone of the Beaufort Sea. In contrast, very few bowheads occurred in this zone during the summers of 1982 and 1983. The 1983-84 BEMP report suggested that these variations in bowhead distribution may be related to variations in food (zooplankton) distribution and availability, which are in turn influenced by both regional and local oceanographic phenomena. Initial assessment of information relevant to this hypothesis is being conducted as part of an ESRF study described earlier (see Project Overview 2). The alternate hypothesis is that changes in whale distribution from 1980-83 may be due to industrial disturbance and displacement of animals. The present study (in consort with the U.S. MMS Behaviour Study) is examining this hypothesis by attempting to document the medium- and long-term behavioural responses of bowheads to industrial activities. In contrast to the BLM study of short-term changes in behaviour (several hours), this program involves study of the movements and behaviour of individual animals over a period of days or weeks.

BEMP PROJECT OVERVIEW NO. 4

TITLE: Marine Mammal Underwater Detection/Census Techniques
PRINCIPAL INVESTIGATORS: Michael C.S. Kingsley and Pierre Richard
AFFILIATION: Fisheries and Oceans Canada, Freshwater Institute
FUNDING SOURCE: OERD and DFO
EXPECTED COMPLETION DATE: March 1988
RELEVANT BEMP HYPOTHESIS NUMBER(S): 1 and 2

BRIEF PROJECT DESCRIPTION

This Research and Development program has two related objectives:

1) development of passive underwater sound detection and localization techniques to improve land- or ice-based visual counts of marine mammals; and

2) development of active underwater detection techniques (sonar) to improve land- or ice-based visual and aerial visual or photographic surveys.

A review study addressing these two objectives was completed in early 1984 to establish the state-of-the-art with respect to passive and active underwater sound techniques and their potential application to the censusing of marine mammals. The study examined technical and logistical limitations of equipment, characteristics of marine mammal vocalizations, and included an evaluation and cost review of various equipment. In 1984, a baseline study of narwhal and white whale vocalizations was initiated in the eastern Arctic.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

The results of this Research and Development project may ultimately have application to various research and monitoring programs directed at marine mammals in the Beaufort region. Passive acoustic techniques were discussed in the 1983-84 BEMP Final Report in relation to Hypothesis No. 1 report, but no conclusions or recommendations were made.

BEMP PROJECT OVERVIEW NO. 5

TITLE: Marine Mammal Remote Sensing Census Techniques
PRINCIPAL INVESTIGATORS: Michael C.S. Kingsley and Pierre Richard
AFFILIATION: Fisheries and Oceans Canada, Freshwater Institute
FUNDING SOURCE: OERD and DFO
EXPECTED COMPLETION DATE: March 1989
RELEVANT BEMP HYPOTHESIS NUMBER(S): 1 to 5

BRIEF PROJECT DESCRIPTION

This Research and Development program has two objectives:

1) development of optimal photo survey techniques for marine mammal surveys through field experimentation and photo interpretation; and

2) determination of the feasibility of using remote sensing data to directly or indirectly monitor marine mammal populations.

A study to review remote sensing systems, and to recommend and specify the optimal system for remote sensing of arctic marine mammals was completed in early 1984. This review was followed by a field program in summer 1984 to evaluate the capability of the recommended system. The data analysis phase of this summer study is still in progress.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

The results of this project will probably have direct application to a variety of marine mammal research and monitoring programs in the Beaufort region.

BEMP PROJECT OVERVIEW NO. 6

TITLE: Beaufort Sea White Whale Study
PRINCIPAL INVESTIGATOR: J. Tom Strong
AFFILIATION: Fisheries and Oceans Canada, Freshwater Institute
FUNDING SOURCE: DFO, NOGAP
EXPECTED COMPLETION DATE: 1987
RELEVANT BEMP HYPOTHESIS NUMBER(S): 2

BRIEF PROJECT DESCRIPTION

This project was initiated in 1981 to obtain information on the population status, distribution and stock identity of white whales hunted in the Mackenzie Estuary, and to collect catch/effort data for the Mackenzie domestic harvest. The overall purpose of the program is to develop management recommendations concerning the Mackenzie white whale population.

Six local persons were contracted in 1984 to obtain information through hunter interviews on catch/effort, total lengths and the sex of harvested whales. In addition, the contractors and DFO summer staff collected biological material from harvested whales, including neccessary material to determine age and reproductive status. Stomach contents were not collected from harvested animals, although stomachs were examined "in situ" and did not contain much prey.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

'Component A' of the monitoring program recommended in the 1983-84 BEMP Final Report included continuation of the annual monitoring of white whale harvest levels in the Mackenzie Estuary. This program is consistent with such recommendations, although it was initiated and is being continued for reasons other than the BEMP process. Information collected during the course of this annual monitoring program is not directly relevant to any of the linkages in Hypothesis No. 2, but does provide important data on various population parameters of the Mackenzie white whale stock (e.g., age, length).

BEMP PROJECT OVERVIEW NO. 7

TITLE: 1984 Beaufort Offshore White Whale Study
PRINCIPAL INVESTIGATOR: Pamela Norton
AFFILIATION: P.N. Research projects, Sidney, B.C.
FUNDING SOURCE: Fisheries and Oceans Canada, NOGAP
EXPECTED COMPLETION DATE: February-March 1985
RELEVANT BEMP HYPOTHESIS NUMBER(S): 2

BRIEF PROJECT DESCRIPTION

The general purpose of this program was to collect information on the Mackenzie (Beaufort) stock of white whales that would assist with proper management of local Inuit harvests, and with assessment of the potential effects of oil and gas exploration and production activities on this population. The specific objectives of the 1985 study were to: (1) document the distribution and relative abundance of white whales in offshore areas during and after the period when peak numbers occur in the Estuary; (2) record movements of whales between nearshore and offshore areas; and (3) examine the observed distribution of white whales in relation to major oceanographic features and sites of relatively intense industry activity in the region.

The study area extended in a west-east direction from the Alaska-Yukon border to approximately Cape Bathurst, and from the coastline seaward to the 7-9/10 concentration pack ice edge. North-south transects within the study area were spaced at an interval that would provide 5 percent coverage of the area and were surveyed by aircraft. Four surveys of the study area were conducted during July and early August, while additional data on the relative abundance and distribution of white whales collected during August-September surveys for bowhead whales (see Project Overview No. 1) will also be discussed in the final report for this study.

This project was to be conducted concurrently with surveys of white whale distribution and relative abundance in the Mackenzie River Estuary (Project Overview No. 6). However, adverse weather conditions during the estuary study will likely prevent comparison of the data collected in the two programs.

The final report for the 1984 offshore white whale survey will discuss the distribution of this population relative to ice conditions and industry activities in the study area. This report will also describe the relative abundance and age composition of white whales in the study area, apparent feeding behaviour, and the distribution of the population in relation to the location and spatial extent of the Estuary.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

Hypothesis No. 2 states four possible effects of facilities and activities associated with offshore hydrocarbon development on white whale harvest. The 1984 white whale study is relevant to the hypothesis that *"Open water ship traffic in the Mackenzie Estuary will alter white whale distribution and lead to changes in harvest levels"*. The study will provide information on the distribution and relative abundance of white whales in the Mackenzie River Estuary and will increase the already substantial database on the distribution of this population in the Beaufort Sea. However, since there were no major changes in annual shipping patterns and intensities in 1984 (e.g., barge traffic through Shallow Bay), the study results will not likely invalidate the existing BEMP hypothesis.

BEMP PROJECT OVERVIEW NO. 8

TITLE: 1984 Beaufort Sea Whale Camp Liaison Program
PRINCIPAL INVESTIGATOR: Vince Steen
AFFILIATION: Tuk Transport Ltd., Tuktoyaktuk, NWT
FUNDING SOURCE: Esso (Operator), Dome, Gulf
EXPECTED COMPLETION DATE: January 1985
RELEVANT BEMP HYPOTHESIS NUMBER(S): 2

BRIEF PROJECT DESCRIPTION

The objectives of this program in 1984 were: (1) to document the timing of break-up of the landfast ice along the Tuktoyaktuk Peninsula and within the Mackenzie River Estuary; and (2) to conduct whale camp visits to ensure that conflicts between the whale hunt and industry activity did not occur or were quickly identified and mitigated.

Study procedures consisted of two aerial reconnaissance surveys of the ice edge from Herschel Island to Baillie Islands on June 19 and 25, 1984. Whale camp visits were conducted at about 4-day intervals during the period from July 10 to August 2.

The ice bridge across Mackenzie Bay and Kugmallit Bay broke on approximately June 22 and June 25, respectively. The date that white whales first entered the Estuary was not recorded in 1984. However, individuals were observed along the ice edge adjacent to the Estuary on the June 19 reconnaissance flight, and presumably started to enter the Estuary soon after the ice bridge broke. There were no conflicts between industry activities and the white whale hunt in 1984.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This annual monitoring program has been ongoing for many years and is expected to continue in the future. Although 'Component A' of the monitoring recommended during Phase I of BEMP included camp visits, this industry program is considered strictly operational in purpose and is intended to permit early identification and mitigation of potential conflicts between hunters and industry activity. Nevertheless, the program has and will continue to provide information relevant to linkage 6 in Hypothesis No. 2.

BEMP PROJECT OVERVIEW NO. 9

TITLE: Reactions of White Whales and Narwhals to Ship Traffic and Icebreaking Along Ice Edges in the Eastern Canadian High Arctic: 1982-1984

PRINCIPAL INVESTIGATORS: Kerry Finley and Rolph Davis

AFFILIATION: LGL Limited, King City, Ontario

FUNDING SOURCE: Industry and Government (Managed by INAC)

EXPECTED COMPLETION DATE: February-March 1985

RELEVANT BEMP HYPOTHESIS NUMBER(S): 2

BRIEF PROJECT DESCRIPTION

The purpose of this study is to determine the reactions of narwhals and white whales to icebreaking activities in Lancaster Sound and Admirality Inlet. Three years of data have been collected in the early summer period during the first passage of the ore carrier MV ARCTIC (with attendant icebreaker support) to Nanisivik Mines. The study involves documentation of the behaviour of whales along the ice edge (1) before the arrival of the ship(s), (2) during the period of ship arrival and icebreaking in the area, and (3) following passage of the vessels and associated disturbance.

Data collection techniques include the following:

- *Aerial surveys:* Aerial surveys were conducted by helicopter in 1982 and 1983 and by twin otter in 1984. Aerial surveys were used to determine changes in whale distribution along the ice edge (all three years) and offshore (1984 only).
- *Ice-Based Observations:* Detailed observations of whale behaviour were recorded by biologists stationed at the ice edge in 1982 and 1983. These observations included general behaviour, dive times and rates of movement, although emphasis was placed on documenting the behavioural reactions of whales to the presence of ships.
- *Acoustic Sampling:* Under-ice hydrophones were employed in the 1982 and 1983 studies. Two types of hydrophones were utilized; a wideband model was used to record sounds in the frequency range of whale communications, while a low noise bender hydrophone was used to record the frequencies of ship generated noise.
- *Whale Vocalizations:* The complex vocal repetoires of white whales and narwhals were documented, and whale vocalizations related to observed behaviour to the extent possible.
- *Ambient Noise:* The natural background levels of ambient noise were determined at the Admiralty Inlet and Lancaster Sound ice edges (1982 and 1983 respectively). Band level and spectrum level analyses were then completed.
- *Ship Noise:* Recordings from the hydrophones were used to determine noise frequency spectra for the MV ARCTIC and JOHN A. MACDONALD. The ship noise levels were then related to coincident information on whale vocalizations, surface behaviour and distances from the vessels in order to document the frequencies and levels of noise that would elicit responses.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

Hypothesis No. 2(c) states that *"Open water ship traffic in the Mackenzie Estuary will alter white whale distribution and lead to changes in harvest levels"*. The present study is the first program of this type conducted in the eastern Arctic and the most comprehensive study of the reaction of white whales to ship traffic initiated to date. Limited studies completed in the Beaufort Sea and elsewhere suggest that white whales have apparently, at least in part, adapted to regular shipping activity. This investigation will provide more complete information on sound transmission, vocalizations and the behavioural response of whales to infrequent ship passages. Although the study is being completed in the eastern Arctic, it is expected that results will still be of value in anticipating and interpreting the observed reactions of white whales to ships in the nearshore Beaufort Sea.

BEMP PROJECT OVERVIEW NO. 10

TITLE:	An Evaluation of Native Harvest Study Methodologies in Northern Canada
PRINCIPAL INVESTIGATOR:	Peter Usher
AFFILIATION:	Peter Usher Consulting Services
FUNDING SOURCE:	Environmental Studies Revolving Fund (ESRF)
EXPECTED COMPLETION DATE:	February-March 1985
RELEVANT BEMP HYPOTHESIS NUMBER(S):	2, 8, 13 and Appendix III of 1983-84 BEMP Final Report (Harvest hypotheses which were not fully examined in Phase I)

BRIEF PROJECT DESCRIPTION

The purpose of this study is to evaluate the methodologies used in the past and present to determine or estimate native harvest of resources, and to assess the usefulness of the existing data. The study will also assess the use of a simpler approach to improve data collection, analysis and utility. The project was initiated because the acquisition of harvest data has typically involved complex, costly and time consuming methods, and has usually produced results which are of limited use for policy decisions by resource managers. The study involves a comprehensive literature search and extensive interviews with individuals who have participated in past resource harvesting surveys, as well as industry and government resource managers who have used the results of these surveys.

The geographic area of emphasis during the investigation is the Northwest Territories, although information from other areas such as northern Quebec will also be examined. The study will focus on questions related to representative sampling, particularly if harvest data are required for the entire geographic range of a species or if adequate information can be obtained by concentrating data collection in a small area.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

Three hypotheses involving native and non-native harvests of resources were developed prior to the second workshop in Phase I of BEMP, although no comprehensive wildlife harvesting survey has been conducted for the geographical area under consideration in this program. The focus of these hypotheses was the effect of changing harvest methods and patterns on VEC populations. However, the direction and magnitude of these changes could not be adequately addressed by the discipline specialists committed in advance to the workshop. In 1984-85, BEMP will include a special workshop to examine resource harvesting issues. The present study is expected to provide information which will be important to consider during this workshop.

BEMP PROJECT OVERVIEW NO. 11

TITLE:	1984 SAR Ice Imagery of the Beaufort Sea
PRINCIPAL INVESTIGATORS:	Petroleum industry personnel
AFFILIATION:	Not applicable
FUNDING SOURCE:	Not applicable
EXPECTED COMPLETION DATE:	Complete
RELEVANT BEMP HYPOTHESIS NUMBER(S):	2

BRIEF PROJECT DESCRIPTION

As part of normal operational monitoring procedures by the petroleum industry, synthetic aperture radar (SAR) overflights were conducted over the Beaufort Sea during ice break-up in 1984. Data are available for each day from June 14 to July 31 and therefore cover the complete period of break-up. Features such as ice boundaries, cracks, leads, ridges and ships' tracks are easily identifiable on SAR imagery. Although, the data collected during this monitoring are proprietary to the well partners, they are available for reference in the Dome offices for the purposes of BEMP-related research.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

Linkages 2 to 4 of Hypothesis No. 2 indicate that icebreaker traffic associated with offshore hydrocarbon development may advance the timing of the break-up of the landfast ice sheet across Kugmallit and Niakunak bays, and thereby affect the white whale harvest. Alternatively, Link 1 in this hypothesis suggest that the presence of artificial islands off the Mackenzie Delta will delay the regional break-up of the landfast ice. The daily SAR imagery of sea ice in the vicinity of several active and abandoned artificial islands in the offshore Beaufort provides an excellent database for the investigation of break-up patterns. The validity of Links 1 and 2 can be easily evaluated through the use of the SAR ice imagery database.

BEMP PROJECT OVERVIEW NO. 12

TITLE: 1984 Beaufort Seal Monitoring Study
PRINCIPAL INVESTIGATOR: Michael C.S. Kingsley
AFFILIATION: Fisheries and Oceans Canada, Freshwater Institute
FUNDING SOURCE: ESRF and DFO
EXPECTED COMPLETION DATE: February 1985
RELEVANT BEMP HYPOTHESIS NUMBER(S): 3

BRIEF PROJECT DESCRIPTION

The purpose of this study is to monitor the abundance and distribution of ringed seal relative to oil and gas industry activities in the Beaufort Sea to determine if these activities are having detectable effects on seals. The 1984 study is the fourth and final year of surveys in this program.

During the 1974-1979 Beaufort Sea Project, aerial surveys were flown every June to count seals hauled out on the sea ice. Analysis of the data collected over the six years indicated large annual fluctuations in the density and estimated abundance of populations of visible seals. In 1981, when hydrocarbon exploration activity in the Beaufort Sea was intensified, a second series of ringed seal surveys with a more restricted but denser coverage was initiated off the Tuktoyaktuk Peninsula. The survey design incorporated north-south transects spaced every 15' of longitude from 129°15'W to 136°30'W off the Mackenzie Delta and Tuktoyaktuk Peninsula. These transects were approximately 160 km long and were rounded to the nearest 20' of latitude at their offshore ends.

A control area in Amundsen Gulf and Prince Albert Sound was included in the study design to allow comparison of any population changes in the Beaufort Sea with variation in an area which is both prime pupping habitat and unaffected by hydrocarbon exploration activities. The transects were spaced every 20' of longitude from 114°40'W to 123°00'W and extended south to 70°30'N in Amundsen Gulf.

No association between low densities of seals and proximity to industrial activity has been found during the previous three years of this program. In fact, it appeared that higher densities of seals occurred near active sites of industry activity in 1982 and 1983. This may be because exploration has been most concentrated in areas near the shear zone where high densities of seals tend to occur. The results of the 1984 surveys are presently being analysed, but appear to be similar to those obtained during the previous years' surveys.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

Hypothesis No. 3 states that *"Marine vessel traffic, seismic activities, dredging operations, aircraft overflights and active offshore platforms/islands will reduce the size of the Beaufort Sea populations of ringed and bearded seals"*. However, the hypothesis was considered unlikely given the anticipated hydrocarbon development scenario for the region, and as a result, no research or monitoring was recommended. However, the present seal monitoring study was initiated in 1981 prior to BEMP, and is directly relevant to Link 1 which states that "Each active offshore platform will result in the exclusion of ringed and bearded seals from some habitat". The results of past seal surveys support the BEMP conclusion that the extent of exclusion would be inconsequential and in most instances limited to the physical extent of the island/structure, and that the cumulative effects of all links in this hypothesis would probably be inconsequential. The results of the 1984 ringed seal monitoring study have not yet been examined with respect to the BEMP conclusions.

BEMP PROJECT OVERVIEW NO. 13

TITLE:	Changes in the Population Dynamics of Ringed Seals in Amundsen Gulf
PRINCIPAL INVESTIGATOR:	Tom Smith
AFFILIATION:	Fisheries and Oceans Canada, Arctic Biological Station
FUNDING SOURCE:	Unknown
EXPECTED COMPLETION DATE:	Unknown
RELEVANT BEMP HYPOTHESIS NUMBER(S):	3, 4 and 6

BRIEF PROJECT DESCRIPTION

This study involves the compilation and integration of extensive amounts of data collected by the Arctic Biological Station on the Amundsen Gulf ringed seal population during the period from 1971 to 1983. This long-term program has included investigation of various aspects of ringed seal population structure, recruitment, annual movements and physiological condition. Samples were collected in several areas within Amundsen Gulf including Minto Inlet, Prince Albert Sound, Prince of Wales Strait and Cape Parry.

Specific aspects of the program involve:

a) *Cohort Analysis:* Annual life tables and cohort analysis from a large collection of specimens will allow estimation of age-specific survivorship.

b) *Reproductive Biology:* Examination of reproductive systems will provide estimates of age-specific reproductive rates and also allow investigation of the mechanism for abortion and failure of some seals to mate. In addition, breeding habitat surveys will provide a direct index of reproduction for each year and serve as a check on information obtained from examination of reproductive systems.

c) *Seasonal and Annual Movements:* Collected specimens will be examined for evidence of geographical segregation of age classes or sexes.

d) *Condition indices* will be derived from measurements of body fat, blood parameters, and in some cases, stomach contents.

Many aspects and components of this research have been presented elsewhere. The overall integration and interpretation of information resulting from this study, including resolution of seasonal and year to year changes, has required the use of computerized techniques of data analysis and simulation.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This program is relevant to Hypotheses No. 3, 4 and 6. There is concern that icebreaker traffic through Amundsen Gulf will affect the ringed seal and polar bear populations. Some effects could result from alterations to ice type, coverage and location. Participants in the second workshop of the Beaufort Environmental Monitoring Project concluded that although such ship-induced destabilization of the Amundsen Gulf ice cover was not highly probable, this area of concern deserved further consideration because of the potential seriousness of resultant impacts on seal and bear populations. Analysis of existing data was recommended to examine the effects of yearly changes in ice conditions on the distribution and abundance of marine mammal populations. The comprehensive time series of ringed seal data for Amundsen Gulf collected by the Arctic Biological Station was identified as an important source of information for such an analysis. Examination of the 12 years of data will allow analysis of the relationship between variations in ice cover (most notably the extreme ice years of 1971, 1978 and 1981) and changes in ringed seal population parameters.

BEMP PROJECT OVERVIEW NO. 14

TITLE:	The MV ARCTIC Ship Track and its Effect on Hunter Travel and the Ice Break-up in Admiralty Inlet, Northern Baffin Island
PRINCIPAL INVESTIGATORS:	Uwe Embacker/Alan Sneyd
AFFILIATION:	FMS Engineers/Canarctic Shipping
FUNDING SOURCE:	NOGAP (INAC)
EXPECTED COMPLETION DATE:	February 1985
RELEVANT BEMP HYPOTHESIS NUMBER(S):	2, 4 and 6

BRIEF PROJECT DESCRIPTION

This study was initiated in response to concerns by Inuit hunters of Arctic Bay that the icebreaking associated with passage of the MV ARCTIC through Admiralty Inlet to Nanisivik Mines would affect their traditional on-ice narwhal hunt. Other concerns that this activity would alter the distribution of white whales and narwhals were examined during a three-year research program summarized earlier (see Project Overview No. 9). The present study specifically addressed the effects of early spring (June-July) icebreaking activities on ice break-up and hunter travel.

The final report will include the following:

a) A ten year retrospective review of the break-up process in Admiralty Inlet using all available remote sensing and satellite imagery data. Particular emphasis will be placed on detection of any changes attributable to the passage of the MV ARCTIC which has occurred only in the last three years.

b) A detailed discussion of the monitoring of break-up during June-July 1984, including on-ice field investigations and observations recorded during helicopter overflights. Photographic records of ice conditions to show changes in ship track width and composition, as well as macro shifts in ice floe geometry, will be presented.

c) The results of track crossing load tests will also be discussed. Inuit hunters were involved in a study that attempted to simulate crossing of the ship track with a skidoo and loaded sled. Emphasis will be placed on description of temporal changes in crossing difficulty, as well as changes following the second (outbound) passage of the ship. Supporting information will include data collected on ice thickness, surface conditions, freeboard, temperature profiles, etc. to document the refreezing and stabilization process.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

Several of the hypotheses discussed in the 1983-84 BEMP Final Report concern the potential effects of ship traffic on the ice stability and subsequent impacts on marine mammal populations. One linkage in Hypothesis No. 2 suggests that icebreaker traffic in the landfast ice in spring will advance the break-up of ice barriers, while another linkage in Hypothesis No. 6 states that "icebreaker traffic in Amundsen Gulf will move the stable ice edge to the east in winter and spring". Direct evidence to confirm or reject either hypothesis linkage is virtually non-existent. The spring voyage of the MV ARCTIC ore carrier through 100 km or more of landfast ice in the past three years is one activity that will allow testing of hypotheses related to ice stability. Therefore, although the study was conducted in the eastern Arctic, it will provide important information to allow prediction of the impacts of winter shipping in the Beaufort Sea.

BEMP PROJECT OVERVIEW NO. 15

TITLE:	Field Evaluation of Infrared Detection for Surveying Marine Mammals
PRINCIPAL INVESTIGATOR:	Richard Fitch
AFFILIATION:	Compuheat Services Canada Ltd., Calgary
FUNDING SOURCE:	Dome, Gulf, Petro-Canada, DFO, INAC, OERD
EXPECTED COMPLETION DATE:	December 1984
RELEVANT BEMP HYPOTHESIS NUMBER(S):	4 and 7

BRIEF PROJECT DESCRIPTION

The purpose of this study was to evaluate the feasibility of using a portable infrared detection system to locate and thereby census ringed seal lairs, and to census seals present on ice surfaces. Infrared cameras and scanning detectors are not a new technology in their basic form, and have been evaluated for potential use in the censusing of seals. The detectors available in the late 1970s were found to be somewhat limited in their capability to detect seals and other marine mammals. The present investigation involves the field testing of a more recent infra-red detection system.

The field tests for this program were conducted in two regions. The capability of the equipment to detect seal lairs was examined in the Resolute Bay area during early May 1984, while the detectability of seals on the ice surface was evaluated in the southeastern Beaufort Sea during mid-June.

During the Resolute Bay tests, it was not possible to record a lair known to be inhabited by a seal. As a result, two simulated conditions were used to examine the feasibility of detecting occupied lairs. The results of the field tests suggested that occupied lairs would be detectable with the portable infrared detection system. However, further tests will be required to substantiate this capability with lairs actually inhabited by seals, and to determine the applicability of the system to routine studies of ringed seals.

Other tests in the Resolute Bay area and those in the Beaufort Sea evaluated the capability of the system to detect seals during aerial surveys. These tests indicated that the system is effective in detecting seals on the ice surface under various wind, temperature and cloud cover conditions.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

Hypothesis No. 4 states that *"Increased frequency of icebreaker traffic through the landfast ice and through Amundsen Gulf will reduce ringed seal pup production"*. The infrared detection evaluation study was not intended to provide information that would directly address any of the links associated with this hypothesis. However, the technique being evaluated, if successful, could have an application in studies conducted to evaluate the density and distribution of ringed seal pupping activities in the above areas or in relation to icebreaker traffic in other regions such as Barrow Strait.

BEMP PROJECT OVERVIEW NO. 16

TITLE:	Study of Arctic Cod and its Importance in Arctic Food Chains
PRINCIPAL INVESTIGATORS:	Aaron D. Sekerak; Rolph A. Davis
AFFILIATION:	LGL Limited, Sidney, B.C.; King City, Ontario
FUNDING SOURCE:	DSS, DFO, INAC
EXPECTED COMPLETION DATE:	March 31, 1985
RELEVANT BEMP HYPOTHESIS NUMBER(S):	6

BRIEF PROJECT DESCRIPTION

The primary goal of this study is to use existing biological material and samples to obtain new information on the ecology of Arctic cod and its importance to seabird and marine mammal populations. Existing specimens of Arctic cod, especially samples of cod or their otoliths obtained from the stomach of various predators (white whale, ringed seal, harp seal, narwhal, fulmar, thick-billed murre, kittiwake, etc.), are being examined during the course of this project. The study is expected to provide new information on year class strength, seasonal and annual variability in abundance, annual variability in growth, diet (primarily of young-of-the-year), common metazoan parasites, and various life history parameters such as age of maturity, weight/length relationships and mortality (to be estimated from the apparent abundance of different year classes).

Samples that are being examined during the study originated from the Chukchi Sea, Beaufort Sea, Central High Arctic, Baffin Bay and Labrador Sea, although the majority of the samples are from areas east of the Beaufort Sea.

The final report will contain a description and interpretation of new information resulting from the analyses, as well as a synthesis of present knowledge regarding the ecology of Arctic cod and its trophic relationships within arctic ecosystems. A number of recommendations for future research will also be provided in the final report. These recommendations are expected to be in the form of discrete hypotheses some of which may require field research programs to test.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

Research on Arctic cod and the role of this species in the diets of its predators is relevant to any impact hypothesis that involves either direct or indirect linkages (through trophic relationships) between industrial development activities and key species of marine mammals or seabirds. This study is particularly relevant to Hypothesis No. 6 *"Icebreaker traffic in Amundsen Gulf will affect the ringed seal and polar bear populations"*, since information may be obtained on spatial and temporal patterns in the abundance and distribution of Arctic cod which in turn affect ringed seal food consumption (Link 9 of Hypothesis No. 6), seal population dynamics and therefore polar bear populations. However, the study will result in only limited new site-specific data for the Beaufort Sea/Amundsen Gulf region due to the small number of samples available for anlaysis from this area. Nevertheless, any improvement in our understanding of the general processes that govern the distribution and abundance of Arctic cod and their availability to predators will increase our ability to design adequate environmental monitoring programs to accompany hydrocarbon development in the Beaufort Sea.

BEMP PROJECT OVERVIEW NO. 17

TITLE: Fish Feeding Ecology
PRINCIPAL INVESTIGATOR: M.J. Lawrence
AFFILIATION: Fisheries and Oceans Canada, Freshwater Institute
FUND'NG SOURCE: DFO, NOGAP
EXPECTED COMPLETION DATE: 1988
RELEVANT BEMP HYPOTHESIS NUMBER(S): 6, 19 and of general interest

BRIEF PROJECT DESCRIPTION

This study has a broad and relatively long-term objective of investigating the feeding habits of pelagic and demersal fish species of the Beaufort Shelf in relation to habitat type and season (open water vs. ice cover). Food resource partitioning will be used for various habitat types, locations and seasons to assess predator-prey overlap among fish species assemblages in the region.

In the first year (1984) of this 5-year study, Arctic cod stomach samples were collected offshore of the Tuktoyaktuk Peninsula during July and September. In future years of the program, it is expected that samples will also be collected in February-March.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

The results of this study will address major data deficiencies regarding the feeding habits of many species of fish in the Beaufort region. This information is of general interest and will contribute to an increased understanding of energy flow in the Beaufort Sea and the trophic relationships among components of the system.

The study is also relevant to Hypothesis No. 6 which states that *"Icebreaker traffic in Amundsen Gulf will affect the ringed seal and polar bear populations"*. Links 7, 8 and 9a of the hypothesis assume that a reduction in zooplankton and epibenthos (prey of Arctic cod) will result in reduced numbers or size of cod, and that this in turn will reduce the population of ringed seals.

Hypothesis No. 19 shown later in this review document states that *"Dredging and deposition of spoils will reduce the bearded seal population"*. This could presumably occur indirectly as a result of dredging-related reductions in the benthic prey organisms of some fish species, which could then result in fewer and smaller fish being available for bearded seal consumption. The present studies on the feeding habits of fish will lead to a better understanding of the plausibility of the above functional relationship.

BEMP PROJECT OVERVIEW NO. 18

TITLE:	Bear Deterrent Research Program
PRINCIPAL INVESTIGATOR:	Paul Gray
AFFILIATION:	GNWT Renewable Resources, Yellowknife, NWT
FUNDING SOURCE:	Various government and industry sources
EXPECTED COMPLETION DATE:	Ongoing
RELEVANT BEMP HYPOTHESIS NUMBER(S):	7

BRIEF PROJECT DESCRIPTION

The general purpose of this research program is to develop successful techniques for deterring bears from sites of human habitation in order to increase human safety and reduce the number of nuisance bear kills. The program has been ongoing since 1981.

Prior to 1984, the focus of the program was on the testing of various detection and deterrent devices. However, the focus was shifted in 1984 to place increased priority on development of a bear deterrent/ detection training and education program. In addition, deterrent field tests were conducted using a new design of 12-gauge, plastic slug on black, grizzly and polar bears. The use of high frequency ultrasonic sounds as a polar bear deterrent was also examined in 1984, while a portable infrared detection system (see Project Overview No. 15) was tested as a scanning detection device.

According to the principal investigator, the training and education program is still being prepared. The results of the test of the new design of plastic slug were unsatisfactory with polar bears. Ultrasound (20 kHz) also had no apparent effect on polar bears, although sound in the 1-3 kHz range did deter some polar bears. The infrared system was cabable of detecting polar bears at a distance of 400 m and functioned satisfactorily with the scanning system.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

Hypothesis No. 7 states that *"The presence of active facilities will result in increased polar bear mortality"*. The two links of this hypothesis suggest that polar bears will be attracted to offshore structures, and the need to maintain worker safety would then necessitate the destruction of some animals. The 1983-84 BEMP report recommended support of ongoing deterrent research programs. This mitigation research program is consistent with the BEMP recommendation and is expected to minimize the need to kill nuisance bears (Link 2).

BEMP PROJECT OVERVIEW NO. 19

TITLE: Alaskan Beaufort Polar Bear Research
PRINCIPAL INVESTIGATOR: Steven C. Amstrup
AFFILIATION: U.S. Fish and Wildlife Service, Anchorage, Alaska
FUNDING SOURCE: Various U.S. and Canadian sources, mostly government agencies
EXPECTED COMPLETION DATE: 1986
RELEVANT BEMP HYPOTHESIS NUMBER(S): 8

BRIEF PROJECT DESCRIPTION

The U.S. Fish and Wildlife Service is presently responsible for the conservation and management of polar bears in the United States. The Alaskan polar bear research program was initiated to assist with this mandate. The principal objectives of the research program are to determine: (1) the size of Alaskan polar bear populations; (2) movements and distribution patterns; and (3) maternity denning areas. During the period from fall 1983 to fall 1984, research was conducted in the Alaskan Beaufort Sea, and in cooperation with the GNWT Wildlife Service, also extended into the Canadian Beaufort region. This research involves mark-and-recapture procedures and radio-telemetry.

The Alaskan polar bear research program has been ongoing since 1967, but the use of radio-telemetry in recent research has led to several information breakthroughs. For example, radio-tracking studies have shown that polar bear movements in the Beaufort Sea are more extensive than previously suggested by the mark-and-recapture data. The program will also provide information on movement of bears from the Alaskan North Slope to the Canadian Beaufort, the location of primary denning areas, trends in polar bear numbers since 1972 and the present size of the population found in Alaskan and Canadian portions of the Beaufort Sea.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

Studies of the type being conducted in the Alaskan polar bear research program were not described in the Phase I BEMP research and monitoring recommendations. Nevertheless, this research does provide information that is indirectly relevant to Link 2 of Hypothesis No. 8: *"Offshore development activities will reduce the harvest of polar bears"*. Link 2 states that "reduced access to polar bears will lead to reductions in the Inuit harvest of polar bears". The results of the Alaskan research will be significant because they show that the Beaufort Sea polar bear population extends from Point Barrow to near Cape Bathurst. Therefore, any activity in Alaska that adversely affects this population could lead to reduced numbers of bears in the Canadian Beaufort (hence a reduced harvest), and perhaps then perceived to be due to offshore hydrocarbon development in the Canadian Beaufort. Although polar bear harvests are regulated in Canada, this is not the case in the U.S. There is presently a concern in Alaska that the unregulated subsistence harvest of polar bears is concentrating on female bears and cubs (which tend to use nearshore areas) to such an extent that it may begin to adversely affect the population if the harvest were to increase further. This research therefore suggests that one or more linkages should be added to Hypothesis No. 8. The following additional linkage should be evaluated during the forthcoming BEMP workshop: The Alaskan subsistence hunt of polar bears will reduce the Beaufort Sea polar bear population, and thereby lead to a reduced harvest of polar bears by the Canadian Inuit.

BEMP PROJECT OVERVIEW NO. 20

TITLE: The Behaviour of Oil in Ice: Effect of Ice Dynamics
PRINCIPAL INVESTIGATOR: Dave Dickins
AFFILIATION: D.F. Dickins Engineering, Vancouver, B.C.
FUNDING SOURCE: Environmental Protection Service, Ottawa
EXPECTED COMPLETION DATE: February 28, 1985
RELEVANT BEMP HYPOTHESIS NUMBER(S): 9, 10, 11

TITLE: Experimental Oil Spills in East Coast Waters
PRINCIPAL INVESTIGATORS: Ian Buist; Dave Dickins
AFFILIATION: S.R. Ross Environmental Research Ltd., Ottawa; D.F. Dickins Engineering, Vancouver, B.C.
FUNDING SOURCE: Environmental Studies Revolving Funds (ESRF)
EXPECTED COMPLETION DATE: August 1985
RELEVANT BEMP HYPOTHESIS NUMBER(S): 9, 10, 11

BRIEF PROJECT DESCRIPTION

The primary objective of both studies is to provide an improved understanding of the behaviour and fate of oil in pack-ice. In the EPS-sponsored study, dynamic processes affecting oil behaviour in moving pack-ice environments are being evaluated for the Beaufort Sea, Lancaster Sound and offshore Labrador regions. Statistical summaries of potential lead dimensions, spacing and closure rates as a function of location and time of year will be developed. The analysis will involve use of remote sensing data including satellite imagery, SAR and SLAR. The results of the study will provide a more comprehensive information base to anticipate the fate of oil in pack-ice for particular locations within these regions, and will be used in planning more realistic tank tests involving oil in broken ice.

The ESRF research program involves the design and execution of three to four experimental crude oil spills in Canadian east coast pack-ice of 5 to 9/10 concentration during March and April 1985. Data necessary to determine the physical and chemical interactions of crude oil with moving ice will be collected during the course of these experiments. However, this project is still in the planning stages and preliminary results are not expected until late in 1985.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

The results of both studies are expected to be relevant to Hypotheses No. 9 through 11 which focus on the possible mortality of polar bears and sea birds as a result of chronic oil spills near offshore structures. Additional information on factors affecting the spatial and temporal distribution and physical/chemical properties of oil in pack-ice areas is expected to be of particular value in determining the potential *susceptibility* of polar bears and sea birds to oil exposure. Both of these resource groups are already known to be very *sensitive* to oil exposure. The results of both studies should also provide information on variability in the properties of oil in pack-ice areas as a function of location, time of year, pack-ice concentration and weather conditions.

BEMP PROJECT OVERVIEW NO. 21

TITLE:	Estimation of Sediment Transport and Nearshore Profile Adjustment
PRINCIPAL INVESTIGATORS:	Keith Philpott/John Harper
AFFILIATION:	Keith Philpott Consultants/Dobrocky Seatech
FUNDING SOURCE:	NOGAP
EXPECTED COMPLETION DATE:	March 31, 1985
RELEVANT BEMP HYPOTHESIS NUMBER(S):	10 and 13

BRIEF PROJECT DESCRIPTION

The objective of this study is to model longshore sediment transport rates in the southeastern Beaufort Sea using existing data. The study focuses on seven sites near the Mackenzie River Delta which are considered to be possible locations for structures (pipelines, weirs, etc .) that extend into the coastal zone: Pauline Cove (Herschel Island), Stokes Point, Kay Point, King Point, Tuktoyaktuk, North Head and Atkinson Point. The study has two components that are being conducted concurrently. In one portion, Philpott Consultants is using non-numerical models to predict longshore sediment movement for the past 14 years. Data for wind speed and direction at Tuktoyaktuk are being used to hindcast the wave climate at each of the seven study sites. Deep water waves are transformed to nearshore waves at each site, and the sediment transport by breaking waves is then computed. This allows an estimation of onshore and offshore sediment movement.

In the second portion of the study (Dobrocky Seatech), a summary of the actual sediment transport that has occurred during the past 14 years is being estimated by time series analyses of aerial photographs and depth sounding at and near the study sites. The success of the modelling exercise will be judged on the basis of the degree of overlap between model prediction and actual "observations" provided by the aerial photography and bathymetric data.

An additional aspect of this study is the long-term evaluation of beach plan shape at King Point during the period from 1972 to 1983.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

Hypothesis No. 10 and 13 describe a possible mechanism for environmental effects associated with chronic oil spills and releases of hydrocarbons and heavy metals from shorebases and shallow water production facilities. In the former hypothesis, the Valued Ecosystem Components are bird populations that may contact surface oil slicks either directly following spills or due to subsequent release of oil trapped in nearshore sediments. In Hypothesis No. 13, the VEC is fish harvest which could be reduced as a result of hydrocarbon tainting (or perception of same) and the uptake of trace minerals. This research program will provide information regarding the possible fate and dispersal of released oil and other contaminants along the Beaufort Sea coast.

BEMP PROJECT OVERVIEW NO. 22

TITLE: Tainting of Fish Resources
PRINCIPAL INVESTIGATORS: Akland and Tidmarsh
AFFILIATION: Martec, Halifax, Nova Scotia
FUNDING SOURCE: Environmental Studies Revolving Funds (ESRF)
EXPECTED COMPLETION DATE: April 15, 1985
RELEVANT BEMP HYPOTHESIS NUMBER(S): 13A

BRIEF PROJECT DESCRIPTION

The major objectives of this study are to: (1) evaluate real or potential concerns associated with the tainting of fish resources (including shellfish) due to oil spills or hydrocarbon development activities; (2) assess the effectiveness of the various methods and procedures used to detect tainting; and (3) identify possible research and monitoring strategies for dealing with tainting.

Case histories of fish and shellfish tainting by petroleum hydrocarbons are being documented through literature searches and communications with various national and international resource agencies, oil companies, and other individuals with expertise in this subject. An important component of the study will be the identification of fishery closures that have resulted from either tainting or the threat of tainting. The second part of the review will include an evaluation of the adequacy of scientific knowledge for dealing with concerns related to tainting. This component of the study will involve an assessment of methods (e.g., taste panels, analytical techniques) used to resolve the problems of human perception of tainting. The merits of conducting laboratory studies with representative commercial species to determine threshold detection levels and dose-response relationships, and the value of including fish tainting as part of an overall strategy for effects monitoring at offshore oil and gas exploration and production sites are also being assessed.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This study has been initiated at least in part because of recommendations provided in relation to Hypothesis No. 13A in the 1983-84 BEMP Final Report, *"Shorebases and shallow water production facilities will release hydrocarbons at sufficient levels such that fish harvest will be reduced through tainting"*. The project is expected to provide information on how hydrocarbons in water, sediments or fish prey species enter fish tissues (Links 1, 2 and 3), how these compounds thereby affect taste, smell and desirability of fish products (Link 4), and finally how tainting or perceived tainting has resulted in reduced fish harvests (Link 5). An important element of the study will be its assessment of the value and feasibility of initiating a monitoring program related to fish tainting.

BEMP PROJECT OVERVIEW NO. 23

TITLE: Biological Importance of Tuktoyaktuk Harbour to Fish
PRINCIPAL INVESTIGATOR: M.J. Lawrence
AFFILIATION: Fisheries and Oceans Canada, Freshwater Institute
FUNDING SOURCE: DFO, NOGAP
EXPECTED COMPLETION DATE: 1985
RELEVANT BEMP HYPOTHESIS NUMBER(S): 13, 14 and of general interest

BRIEF PROJECT DESCRIPTION

This study was initiated in 1981 and is presently nearing completion. Although the fish of Tuktoyaktuk Harbour were the primary emphasis of the study, considerable information has been obtained on primary and secondary production and the species composition of the phytoplankton, zooplankton and macrobenthic invertebrate communities in the area. The products of the study are expected to be: (1) a report discussing the ecology of fish in Tuktoyaktuk Harbour; (2) resource maps of the harbour; (3) recommendations for management/development options related to land use planning; (4) contributions to a report on fish in nearshore areas along the Tuktoyaktuk Peninsula; and (5) a technical report on benthic species and community associations.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This research will provide basic descriptive information on biological communities that may be typically found in small bays along the Tuktoyaktuk Peninsula. In addition, important trophic relationships (i.e., fish feeding habits) within the study area will be identified. Descriptive data and information on interrelationships among communities and species resulting from this study will be useful in determining the need for and possible focus of monitoring programs related to nearshore fish populations and their habitat.

The results of this program are also expected to be relevant to the ongoing evaluation of two hypotheses discussed in the 1983-84 BEMP Final Report. Information collected during past and ongoing research in Tuktoyaktuk Harbour will provide useful descriptive information in relation to Hypothesis No. 13, and aid in the interpretation of any monitoring directed at measurement of the effects of chronic oil spills and other possible disturbances in this area of relatively intense petroleum industry activity. In addition, this research is relevant to Hypothesis No. 14 which suggests that movements of broad whitefish could be affected by the presence of nearshore structures.

BEMP PROJECT OVERVIEW NO. 24

TITLE:	Fate of Hydrocarbons
PRINCIPAL INVESTIGATOR:	John Harper/David Green
AFFILIATION:	Dobrocky Seatech/Seakem Oceanography
FUNDING SOURCE:	Environmental Studies Revolving Funds (ESRF)
EXPECTED COMPLETION DATE:	June 30, 1985
RELEVANT BEMP HYPOTHESIS NUMBER(S):	13, 10, and 9

BRIEF PROJECT DESCRIPTION

Contrary to popular belief, observational information suggests that oil stranded on low energy tidal flats may persist for relatively short periods. This is due to the limited adhesion of oil to tidal flat substrates. The purpose of this study is to improve our understanding of the physical and chemical factors influencing the persistence of oil stranded in low wave-exposure tidal flat environments.

The study includes a detailed review of literature available for previous oil spills, as well as a series of laboratory experiments. The laboratory investigations are designed to test four principal hypotheses:

(1) *Tidal range hypothesis:* oil retention and penetration is positively correlated with non-marine exposure time, which is controlled by the position of the stranded oil in the tidal range;

(2) *Organic content hypothesis:* oil retention is positively correlated with the organic content of fine-grained substrates;

(3) *Loading hypothesis:* oil retention in fine-grained substrates is positively correlated with loading levels; and

(4) *Sediment size hypothesis*: oil retention is negatively correlated with fine sediment content (silt-/clay) of the intertidal flat substrate type.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This project is relevant to BEMP because it will provide a better understanding of the fate of oil stranded in the intertidal zone. This information should permit a more thorough evaluation of the scale (space and time) of impacts that chronic oil spills could have on fish, marine mammals and birds of the southeastern Beaufort Sea.

BEMP PROJECT OVERVIEW NO. 25

TITLE: Beaufort Sea Shorebase Monitoring Program (1984)
PRINCIPAL INVESTIGATOR: Russell Shearer
AFFILIATION: Environmental Protection Service (Yellowknife)
FUNDING SOURCE: NOGAP
EXPECTED COMPLETION DATE: March 31, 1985
RELEVANT BEMP HYPOTHESIS NUMBER(S): 13

BRIEF PROJECT DESCRIPTION

The Beaufort Sea shorebase monitoring program, initiated in 1982, is a multi-year project with the following objectives:

(1) to monitor the occurrence of heavy metals and hydrocarbons in the sediments at shorebases and support developments along the Tuktoyaktuk Peninsula to obtain information that can be used to evaluate marine environmental quality and the effectiveness of regulatory controls;

(2) to measure baseline petroleum hydrocarbon concentrations in sediments along the shoreline of the Tuktoyaktuk Peninsula from Tuktoyaktuk to McKinley Bay; and

(3) to investigate the relationship between sediment contaminant concentrations and sediment properties and the hydrodynamic history in the nearshore zone along the Tuktoyaktuk Peninsula.

Sampling for the third (1984) year of the project was completed, and a contract to analyse the data from this program is expected to be issued early in 1985. However, an interpretive report describing the results of the first three years of the project is not expected until late 1985.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This project will be useful in evaluating Hypothesis No. 13 which states that *"Shorebases and shallow-water production facilities will release (a) hydrocarbons and (b) heavy metals at sufficient levels such that fish harvest will be reduced through tainting and heavy metal accumulations"*. The results of this program will document (1) the background (pre-development) concentrations of metals and hydrocarbons in Beaufort Sea sediments, and (2) any changes in the concentration of metals and hydrocarbons with time.

BEMP PROJECT OVERVIEW NO. 26

TITLE: Fish Migration Along the Tuktoyaktuk Peninsula
PRINCIPAL INVESTIGATORS: Bill Bond; Ken Chang-Kue
AFFILIATION: Fisheries and Oceans Canada, Freshwater Institute
FUNDING SOURCE: DFO, NOGAP
EXPECTED COMPLETION DATE: 1987
RELEVANT BEMP HYPOTHESIS NUMBER(S): 14

BRIEF PROJECT DESCRIPTION

This year was the first of a proposed 4-year study to investigate movements of broad whitefish from freshwater lake-stream systems on the Tuktoyaktuk Peninsula to overwintering areas that presumably occur in the Mackenzie River estuary. The study compliments an investigation of the movements of mature spawners that was conducted mainly on the delta estuary and in upstream regions of the Mackenzie River, although this research focuses on the non-spawning segment of the broad whitefish population. Data collected to date suggest that these individuals spend a number of years living in freshwater systems before they migrate back to the Beaufort Sea. The program in 1985 will include the tagging of broad whitefish from Kukjuktak Creek on the Tuktoyaktuk Peninsula.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This study is most pertinent to Hypothesis No. 14 which states that *"Nearshore structures will disrupt the nearshore band of warm brackish water along the Tuktoyaktuk Peninsula and reduce the broad whitefish population"*. The underlying assumption of this hypothesis is that broad whitefish use the warm brackish water found along the Tuktoyaktuk Peninsula as a migratory route between spawning or overwintering areas in the Mackenzie River or Estuary and rearing areas in freshwater lakes on the Peninsula. Interruption of this route, for example, by the diversion of coastal waters to offshore areas by long causeways, could have population wide effects on the broad whitefish that inhabit the region through decreased survival (Link 4a) or decreased growth and reproductive potential (Link 4b). This study will address major data deficiencies regarding the seasonal use of nearshore waters by broad whitefish in the region.

BEMP PROJECT OVERVIEW NO. 27

TITLE:	Fish Movement and Habitat in Relation to the ARCO Causeway in Prudhoe Bay, Alaska
PRINCIPAL INVESTIGATORS:	Larry Moulton; Bill Griffiths
AFFILIATION:	Woodward Clyde Inc., Walnut Creek, California; and LGL Limited, Sidney, B.C.
FUNDING SOURCE:	Prudhoe Bay Unit
EXPECTED COMPLETION DATE:	February 1985
RELEVANT BEMP HYPOTHESIS NUMBER(S):	14, 15

BRIEF PROJECT DESCRIPTION

This study was conducted from 1 July to 20 September 1984 in coastal regions of the Alaskan Beaufort Sea between Gwyoyr Bay and the Sagavanirktok River delta. The overall objective of the study was to determine the effects of the Prudhoe Bay causeway on fish, their physical habitat and prey. A total of 26 stations were sampled during the course of the field studies, usually on a daily basis. Physical variables measured at each station included temperature, salinity, wave height and turbidity, while fish prey organisms (drop net samples) and fish (fyke net samples) were also collected at each site. A total of about 55,000 fish, mostly broad whitefish, Arctic cisco, least cisco and Arctic char, were marked by either freeze branding or Floy tags to obtain data on individual fish movements through mark-recapture techniques. The results of the research program are presently being analysed.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This study is of obvious and direct relevance to Hypothesis No. 14, *"Nearshore structures will disrupt the nearshore band of warm brackish water and reduce the broad whitefish population"* and Hypothesis No. 15, *"Nearshore structures will disrupt the nearshore band of warmer brackish water and will reduce the Alaskan population of Arctic cisco."* Not only are the same species of fish (Arctic cisco) involved in the case of the latter hypothesis, but the same population could be affected by both the Prudhoe Bay causeway and all nearshore structures constructed between the Mackenzie Delta and the westward limit of Arctic cisco distribution in the Alaskan Beaufort.

BEMP PROJECT OVERVIEW NO. 28

TITLE:	North Slope (Yukon Coast) Impact Assessment
PRINCIPAL INVESTIGATOR:	Bill Bond
AFFILIATION:	Fisheries and Oceans Canada, Freshwater Institute
FUNDING SOURCE:	DFO, NOGAP
EXPECTED COMPLETION DATE:	1988
RELEVANT BEMP HYPOTHESIS NUMBER(S):	15, also of general interest

BRIEF PROJECT DESCRIPTION

Planning for this 5-year study began in 1984. Its main objectives are to:

1. obtain baseline biological descriptions of the marine and anadromous fishes utilizing nearshore habitats along the Yukon coast (species composition and distributions, age and growth, sex and maturity, food habits);
2. describe the longshore migratory patterns of anadromous fish (both spatially and seasonally);
3. identify specific areas that may be of importance to marine and anadromous fishes as feeding, spawning, nursery, or overwintering habitat; and
4. characterize inshore habitats (to the 5 m isobath) in terms of temperature and salinity, and relate these parameters to fish distribution and movement patterns.

An aerial survey of the study area was conducted in 1984. During the period from 1985 to 1987, gillnets, trapnets and seines will be used to sample marine and anadromous fish populations between Kay Point and Calton Point, an area that includes Phillips Bay, the Babbage River Estuary, Stokes Point, Roland Bay, and the eastern end of Workboat Passage. Most sampling will occur in the open water season, although limited winter field studies are also anticipated. The extent of anadromous fish movements will be evaluated through the use of conventional (Floy) tags.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This study is particularly relevant to Hypothesis No. 15 which states that *"Nearshore structures will disrupt the nearshore band of warmer brackish water and will reduce the Alaskan population of Arctic cisco"*. It will define use of the nearshore zone as a migration corridor for Arctic cisco and other species. The results of this 5-year program could verify or disprove the underlying assumption of Hypothesis No. 15. The assumption is that "Alaskan Arctic cisco" spawn in the Mackenzie River and then juveniles migrate along the Yukon coast to spend a number of years in Alaskan waters before mature or nearly mature fish return to the Mackenzie River to spawn.

In addition, this study is expected to provide basic descriptive information on other fish species which occur along the Yukon coast. These data will provide the basis for evaluation of the need for future monitoring programs related to hydrocarbon development activities in this part of the southeastern Beaufort Sea.

BEMP PROJECT OVERVIEW NO. 29

TITLE: Nearshore Benthic Monitoring
PRINCIPAL INVESTIGATORS: M.J. Lawrence
AFFILIATION: Fisheries and Oceans Canada, Freshwater Institute
FUNDING SOURCE: DFO, NOGAP
EXPECTED COMPLETION DATE: 1990
RELEVANT BEMP HYPOTHESIS NUMBER(S): 19 and of general interest

BRIEF PROJECT DESCRIPTION

The objectives of this study are to determine annual and seasonal variability in the standing stock of the macrofaunal and meiofaunal populations of benthos in various embayments along the Beaufort Sea coastline.

Van Veen grabs and small diameter corers will be used to sample macrofauna and meiofauna, respectively. A random-stratified sampling strategy will be employed at locations with a similar mud-type substrate and minimum bottom slope. Sampling stations will be located at depths of 3 to 5 m, 10 to 12 m and 15 to 20 m. Sedimentation rates, salinity, temperature, sediment texture and the organic content of substrates will be measured to determine factors influencing species abundance and biomass. The size of predominant species of the macrobenthos will also be determined. Carbon, nitrogen and phosphorous determinations will be conducted on collected sediments, while water column measurements will include determinations of chlorophyll, total particulate concentrations and analysis of particulate and dissolved carbon, nitrogen and phosophorous.

Sampling will be conducted in February/March and August of each year at the 10 to 12 m depth strata. In the second year, SCUBA techniques will be used to enable direct (c.f. remote) sampling of the benthos. The efficiency and sampling biases introduced by the Van Veen grab will then be analysed. The first year of this study has been completed and samples are presently being analysed.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This study is of direct relevance to Hypothesis No. 19 which states that *"Dredging and deposition of spoils will reduce the bearded seal population"*. More specifically, it will examine the effects of dredging on benthic invertebrates in Tuktoyaktuk Harbour and natural undisturbed populations in other bays. This information will be useful to determine the validity of Link 7 in Hypothesis No. 19, which assumes that dredging will reduce bearded seal populations as a result of decreased abundance of one of their primary sources of food (i.e., benthic invertebrates).

BEMP PROJECT OVERVIEW NO. 30

TITLE:	Mackenzie Shelf Fisheries Habitat Research
PRINCIPAL INVESTIGATORS:	M.J. Lawrence; Larry deMarch
AFFILIATION:	Fisheries and Oceans Canada, Freshwater Institute
FUNDING SOURCE:	DFO, NOGAP
EXPECTED COMPLETION DATE:	1984
RELEVANT BEMP HYPOTHESIS NUMBER(S):	Of general interest

BRIEF PROJECT DESCRIPTION

The organization and planning for this long-term study were initiated in 1984. The major objectives of the program will be to:

1. identify in both spatial and temporal terms, the areas of the Mackenzie Shelf from Demarcation Point to Cape Bathurst that are of significance to marine and estuarine fish; and
2. characterize important or critical marine habitats in terms of their physical-chemical environment, biotic community structure or production.

The program is expected to include investigation of seasonal fish abundance and distribution (including ichthyoplankton), and the salinity, temperature, nutrients, oxygen, inorganic carbon, light regimes, chlorophyll, zooplankton, phytoplankton, suspended solids, primary production and benthic microinvertebrates in important marine habitats.

Two sampling programs were conducted in 1984, largely to test and compare the effectiveness of sampling gear. Samples were collected at ten and six stations in July and September, respectively. Samples or measurements were obtained on fish, plankton, benthic microinvertebrates and a variety of physical-chemical parameters. At present, ongoing program activities include analysis of 1984 samples, literature reviews and an evaluation of the applicability of satellite imagery techniques for future research.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This study is indirectly relevant to BEMP because it will provide basic descriptive information on fish and fish habitat characteristics to support research and monitoring associated with several hypotheses. It will also provide baseline data necessary to determine the need for monitoring studies related to new hypotheses.

BEMP PROJECT OVERVIEW NO. 31

TITLE: Whitefish Migration in the Mackenzie River and Estuary
PRINCIPAL INVESTIGATOR: Ken Chang-Kue
AFFILIATION: Fisheries and Oceans Canada, Freshwater Institute
FUNDING SOURCE: DFO, NOGAP
EXPECTED COMPLETION DATE: March 1985
RELEVANT BEMP HYPOTHESIS NUMBER(S): Of general interest

BRIEF PROJECT DESCRIPTION

This study is a continuation of an investigation involving the radio tracking of broad whitefish and to a lesser extent lake whitefish. Specimens have been captured in the lower Mackenzie Delta at Horseshoe Bend in Middle Channel during the fall, released and then their locations periodically monitored through the use of fixed wing aircraft. Most of the information that has resulted from this study relates to location of overwintering in areas in or near the Mackenzie River Estuary and spawning areas in regions upstream of the Delta.

Most data obtained during the course of this investigation has been for broad whitefish, since their large size allows the use of radio tags with less stress than possible with the smaller species. Data collected to date indicates that mature spawners of the year begin moving into Delta waters during mid-September. Broad whitefish then hold or move slowly upstream until late October, when they begin a concentrated upstream movement to spawning areas. Spawning is likely completed by mid-November. Shortly after spawning, broad whitefish move downstream and are in the Mackenzie River Estuary by early December, where they remain with little movement until March. Results to date suggest that overwintering occurs near Whitefish Point, and in Shallow Bay and Tuktoyaktuk Harbour.

Preliminary findings with mature lake whitefish suggest that they have movement patterns similar to those of broad whitefish, but these movements occur about two weeks earlier.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

Whitefish populations in the Beaufort region are anadromous, and it is presently assumed that virtually all individuals found in the BEMP study area originate in the Mackenzie River drainage. Therefore, while this whitefish migration study is conducted largely in freshwater, some information from the investigation will likely be relevant to other research or monitoring designed specifically to address BEMP hypotheses. For example, data on the timing of spawning migration will be important in determining (1) when mature fish leave the Beaufort Sea or Mackenzie River Estuary region, and thus could not be affected by industrial activities, and (2) probable periods of migration through coastal waters of the Beaufort Sea. Identification of overwintering areas in estuarine waters of the Beaufort region is of obvious interest.

BEMP PROJECT OVERVIEW NO. 32

TITLE: Whitefish Stock Distribution
PRINCIPAL INVESTIGATOR: J. Reist
AFFILIATION: Fisheries and Oceans Canada, Freshwater Institute
FUNDING SOURCE: DFO, NOGAP
EXPECTED COMPLETION DATE: March 1985
RELEVANT BEMP HYPOTHESIS NUMBER(S): Of general interest

BRIEF PROJECT DESCRIPTION

The purpose of this study is to determine the discreteness and number of broad whitefish stocks in the Mackenzie River drainage through morphometric, meristic and electrophoretic techniques. Samples of whitefish have been obtained in the Mackenzie Delta and at several locations upstream. These specimens will be examined to determine the usefulness of specific characteristics as stock identifiers and to determine if separate stocks exist within the drainage.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

This study is of general interest because it may provide data which will aid in assessment of the possible magnitude or severity of the effects of hydrocarbon development on broad whitefish. If separate populations of broad whitefish exist in the region, they may be more susceptible to some development activities, particularly if such populations remain as relatively discrete units while in the Beaufort Sea.

BEMP PROJECT OVERVIEW NO. 33

TITLE:	Water Colour and Temperature in the Southern Beaufort Sea: Remote Sensing in Support of Ecological Studies of the Bowhead Whales
PRINCIPAL INVESTIGATOR:	Gary Borstad
AFFILIATION:	Arctic Laboratories Ltd.
FUNDING SOURCE:	Institute of Ocean Sciences, DFO
EXPECTED COMPLETION DATE:	1984
RELEVANT BEMP HYPOTHESIS NUMBER(S):	1

BRIEF PROJECT DESCRIPTION

This project was the first attempt to obtain and systematically examine environment data available from satellite imagery and to relate this information to the distribution of bowheads over large areas of the southeast Beaufort Sea. Both aircraft and satellite remote sensing techniques were used to map surface temperature and water colour patterns caused by phytoplankton and suspended sediments in surface waters. Although these measures of the surface properties of the ocean environment do not provide direct information concerning the distribution and abundance of zooplankton, they can be used to locate and map surface discontinuities and boundaries where zooplankton are often concentrated in large numbers (Denman and Powell 1984). As recognized in the past from conventional oceanographic measurements (e.g., Nasu 1966, cited in Gaskin 1982), Borstad (1984) found that large numbers of whales often tended to be located near oceanographic features such as fronts, eddies and other discontinuities. These features were recognizable in aerial water colour maps or satellite thermal and broad band visible imagery (NOAA-7, AVHRR bands 4 and 1, respectively).

Borstad (1984) examined six NOAA-7 thermal and broad band visible images for the period from 1980 and 1983, and noted that the Herschel/Yukon Coast and Cape Bathurst (west Franklin Bay) areas commonly experienced turbulence or upwelling. It was suggested that local physical aggregation of zooplankton in these areas may be important for feeding bowhead whales.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

Hypothesis No. 1 states that *"Ship traffic, seismic exploration and active offshore structures will cause a reduction in the western Arctic population of bowhead whales"*. This study, like the Bowhead Feasibility Study (Project Overview No. 2), examined an interrelated hypothesis: bowhead whale distribution patterns are related to oceanographic factors which influence the distribution of the food supply of this population. The research is relevant to BEMP because it will provide information on oceanographic factors that may directly and indirectly influence the distribution of bowhead whales.

BEMP PROJECT OVERVIEW NO. 34

TITLE: Alaskan North Slope Borough Contributions to Bowhead Research
PRINCIPAL INVESTIGATORS: T. Albert, C. George
AFFILIATION: Alaskan North Slope Borough
FUNDING SOURCE: North Slope Borough and others
RELEVANT BEMP HYPOTHESIS NUMBER(S): 1

BRIEF PROJECT DESCRIPTION

There was no representative of the North Slope Borough at previous BEMP workshops. Their representative at the 1985 workshop (C. George) provided a description of some of the research relevant to bowhead whales that has been conducted over the past few years by or for the Borough. Emphasis in the following project overview has been placed on the research of most relevance to BEMP Hypothesis No. 1. This includes:

Observations on the Digestive System of the Bowhead Whales

Several stomachs were collected from bowheads taken in the subsistence harvest by the Alaskan eskimos, and have been examined as part of a study of the functional anatomy of the digestive tract. This research was funded, along with other studies, to describe the basic biology of the bowhead whale. Its results can be used in part to aid in the determination of basic feeding mechanisms of bowheads.

The stomach was found to be four-chambered and, therefore, similar in structure to stomachs of other cetaceans. The first chamber (forestomach) is non-glandular and possibly serves as a temporary food storage site. However, this forestomach is comparatively small in the bowhead. Based on limited observations, the first chamber did not appear to exceed 40 gal (150 L) in capacity, even in whales over 50 ft (16 m) in length. The glandular region of the stomach has a connecting channel between the fundic and pyloric chambers that is 5 cm in diameter. These findings suggest that the bowhead may not be capable of very large food intake, but rather must feed relatively continuously on small amounts of food.

All of the many stomachs examined in conjunction with the spring hunt at Point Hope, Barrow and Wainwright have been empty. Whales taken at St. Lawrence Island are seldom available for internal examination. However, one of the few stomachs that have been examined contained large quantities of invertebrates. This suggests that some winter feeding may occur. The stomachs of whales examined at the time of the fall harvest at Kaktovik all contained some food suggesting that feeding was occurring near the Yukon/Alaska border.

Possible Reduction in the Fall Whale Harvest off Point Barrow

During discussions with the Hypothesis No. 1 workshop subgroup, C. George of the North Slope Borough indicated that whaling captains from Barrow are concerned that: (1) the fall migration of bowheads has been displaced seaward in the region of Barrow in recent years; and (2) this possible displacement may be due to petroleum industry operations, particularly marine seismic exploration. The issue is contentious because there is so little information and too few aerial survey data for the specific area to statistically demonstrate whether or not any such displacement has occurred. In September 1984, however, some whales were observed feeding close to the coast east of Barrow as reported prior to industry presence in the region. At the same time, no bowhead displacement has been observed in other areas of the Beaufort Coast, including the area near Prudhoe Bay where industry activity has been greater than that near Barrow. The issue of displacement is recognized as one for which more rigorous data are required before any definitive statement can be made. The North Slope Borough is involved in other areas of bowhead whale research that are of general interest but provide no

specific information related to the BEMP Hypothesis No. 1. These programs include observations on the morphology of the skin of bowheads, and analysis of tissue levels of trace organics and heavy metals in samples taken from the subsistence harvest of bowhead whales.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

The North Slope Borough studies of the bowhead digestive system are relevant to Links 5, 6 and 7 of Hypothesis No. 1. The information on the Barrow Alaska bowhead harvest could be relevant to Link 1 but is unsubstantiated at the present time.

BEMP PROJECT OVERVIEW NO. 35

TITLE: Primary Production in the Alaskan Beaufort Sea in Relation to Bowhead Whale Distribution

PRINCIPAL INVESTIGATOR: Don Schell
AFFILIATION: University of Alaska

RELEVANT BEMP HYPOTHESIS NUMBER: 1

BRIEF PROJECT DESCRIPTION

Available data on the annual primary productivity in the Beaufort and Chukchi seas have been presented as contours on maps of areas offshore of Alaska. These maps depict areas where high rates of carbon fixation have been measured and show a full order of magnitude decrease in productivity across contours to the Beaufort Sea north of Alaska. An area of relatively high productivity (in relation to the remainder of the Beaufort) is evident near the Alaska-Canada border, but few data are available for the eastern Beaufort Sea.

Superposition of primary productivity contours on the locations of historical bowhead whale captures for the month of August during the period 1848-1919 results in a high degree of correlation between areas of production and harvest. This is consistent with the overall hypothesis that increased primary production will lead to higher rates of secondary production (reflected in greater zooplankton biomass), and that this secondary production may then support feeding bowheads.

It is cautioned, however, that this evidence is circumstantial because of the large number of intermediate steps from primary production to past bowhead harvest location. At the same time, the location of historic whale kills is dependent on the location of whalers, particularly with respect to sites where whaling crews traditionally overwintered and where ice conditions allowed most access to bowheads.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

The present research could be relevant to Links 5 and 6 of Hypothesis No. 1. Link 5 states that available aquatic habitat determines the level of available food, while Link 6 suggests that the amount of available food and the time available for feeding determine the energy intake.

Primary productivity mapping provides an indirect indication of potentially important bowhead feeding areas. The author suggests that extension of existing primary productivity mapping into the eastern Beaufort Sea may be of some value in the identification of prime bowhead whale feeding habitats.

BEMP PROJECT OVERVIEW NO. 36

TITLE: Carbon Isotope Studies on Bowhead Whales
PRINCIPAL INVESTIGATOR: Don Schell
AFFILIATION: University of Alaska
RELEVANT BEMP HYPOTHESIS NUMBER: 1

BRIEF PROJECT DESCRIPTION

The carbon isotope content of muscle and oil were determined in samples obtained from a small number of whales harvested in Alaska. These analyses suggest that this technique may provide relevant data on the fraction of bowhead food that is obtained from upwelling zones. The remainder of bowhead annual energy intake is expected to be derived from productivity in waters that are well equilibrated with atmospheric radiocarbon.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

The present research could be relevant to Links 6 and 7 of Hypothesis No. 1: the amount of available food and the time available for feeding determine the energy intake (Link 6); and energy intake and expenditures determine the energy balance of a bowhead whale (Link 7).

The carbon isotope content of bowhead whale tissue may provide important information on the dependency of this population on specific habitats within its range, particularly if supporting data on the carbon isotope content of prey organisms are available for various locations along its migration corridor. These data may, therefore, help to resolve the question of winter feeding of bowheads. The latter investigations are currently in progress.

BEMP PROJECT OVERVIEW NO. 37

TITLE:	Observations on the Behaviour of the Bowhead Whale in Relation to Offshore Industrial Activity in the Beaufort Sea
PRINCIPAL INVESTIGATOR:	J. Richardson
AFFILIATION:	LGL Limited, King City, Ontario
FUNDING SOURCE:	U.S. Minerals Management Services
EXPECTED COMPLETION DATE:	Fall 1985
RELEVANT BEMP HYPOTHESIS NUMBER(S):	1

BRIEF PROJECT DESCRIPTION

During the past 5 years, the short-term behavioural reactions of summering bowhead whales to offshore industrial activities in the Canadian Beaufort Sea have been examined (Richardson 1985a). The two approaches used in this research have been (1) opportunistic observations of whales near oil industry operations, and (2) experiments designed to determine reactions of individuals to simulated industrial activities. Disturbance sources examined included aircraft, marine vessels, seismic operations and drillships.

Richardson (1985a) concluded that bowhead behaviour can be affected markedly by ships and aircrafts, although changes in behaviour are only temporary and occur at relatively short distances from disturbance sources. Reactions of whales to more continuous noise sources (e.g., drilling, dredging, distant seismic operations) were less obvious. Bowheads appeared to behave normally when observed very near these sources of continuous industrial noise, with some tendency for animals to orient away from these sites at the onset of noise production. This research has not examined whether bowheads are subjected to stress or other negative effects of ongoing industrial operations.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

Hypothesis No. 1 states that *"Ship traffic, seismic exploration and active offshore structures will cause a reduction in the western Arctic population of bowhead whales"*. More specifically, active drilling or production islands have associated ship and helicopter traffic, and these mobile noise sources could act in conjunction with on-island activities to produce a zone of at least partial exclusion of whales from around offshore islands and platforms.

This 5-year program of behavioural research provides some of the most direct and long-term data to address Links 1 to 4 in Hypothesis No. 1.

BEMP PROJECT OVERVIEW NO. 38

TITLE:	The Behaviour of the Bowhead Whales in the Presence of Operating Seismic Vessels
PRINCIPAL INVESTIGATORS:	J. Richardson and D. Ljungblad
AFFILIATION:	LGL Ltd. and Naval Ocean Systems Center (respectively)
FUNDING SOURCE:	—
COMPLETION DATE:	Fall 1985
RELEVANT BEMP HYPOTHESIS NUMBER:	1

BRIEF PROJECT DESCRIPTION

In 1984, two distinct studies of the short-term behavioural reactions of bowhead whales to seismic vessels were undertaken in the Alaskan Beaufort Sea (Ljungblad et al. 1985; Richardson 1985b). Experiments were conducted on both an opportunistic basis and under controlled conditions with a dedicated seismic ship. Detailed observations were recorded from circling aircraft. A series of tests was conducted using several seismic vessels in different geographic areas, and the observed behaviour of bowhead whales was generally consistent between the two studies and with previous investigations.

The general response of whales was to move away from an active approaching seismic vessel. Noticeable and statistically verifiable responses were limited to bowheads within 6 or 7 km of the vessels. Experiments with an air gun and a full-scale seismic vessel showed that some bowheads moved when the noise source was very close. Ljungblad et al (1985) found that bowhead whales exhibited changes in behavioural response to the approach of active seismic vessels at distances ranging from 3.5 to 6.7 km, while Richardson (1985b) showed that bowhead activities were rarely altered in any noticeable manner when the distance to noise sources was greater than 6 km. This author also suggested that whales resumed pre-experiment behaviour within a short period (generally less than an hour) following termination of seismic operations.

Richardson (1985b) concluded that the short-term behavioural reactions of bowhead whales to seismic exploration are surprisingly minor in view of the high intensity of the noise pulses at distances up to many kilometres from an active vessel. This study focused on short-term behavioural reactions and was not designed to document longer-term behavioural responses of whales to seismic operations or their potential exclusion from an industrial zone.

RELATIONSHIP AND RELEVANCE TO THE BEAUFORT ENVIRONMENTAL MONITORING PROJECT

The present research is relevant to Links 2, 3 and 4 of Hypothesis No. 1 which state: ship traffic will exclude bowheads from a zone around the ship track (Link 2); each passage of a ship will reduce the feeding time available to bowheads (Link 3); and each passage of a ship will increase the energy expenditure of whales due to avoidance behaviour (Link 4). It is also indirectly relevant to Link 1 which addresses active offshore island or platforms.

APPENDIX B

LIST OF PARTICIPANTS
1985 BEAUFORT ENVIRONMENTAL MONITORING PROJECT WORKSHOP
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APPENDIX C

RESPONSE TO A PROPOSAL FOR A NEW VALUED ECOSYSTEM COMPONENT AND RELATED IMPACT HYPOTHESES

The following proposal to add the coastal zone to the list of VECs considered as part of the Beaufort Environmental Monitoring Project was submitted to the BEMP Management Committee during the most recent workshop.

PROPOSED VEC AND IMPACT HYPOTHESES

TO: Wayne Duval
Chairman of BEMP Management Committee

FROM: John Harper
Dobrocky Seatech
(representing EMR)

DATE: February 6, 1985

Attached is:

1. a justification for including the COASTAL ZONE as a VEC (again); and
2. impact hypotheses and justification for links.

As you know, this VEC has been kicked around since the first workshop, yet there has been no written justification for excluding the coastal zone from the review process. If the justifications are rejected by the management committee, it is time to provide a written justification (in the report) outlining the specific rationale for rejecting the coastal zone as a VEC. Both EMR and I would appreciate this.

THE COASTAL ZONE AS A VEC

In the first BEMP workshop the COASTAL ZONE was identified as a VEC in that:

1. The COASTAL ZONE is an important resource to local populations, particularly during the summer period when it provides the primary base for traditional harvesting (hunting, fishing, whaling, etc.).

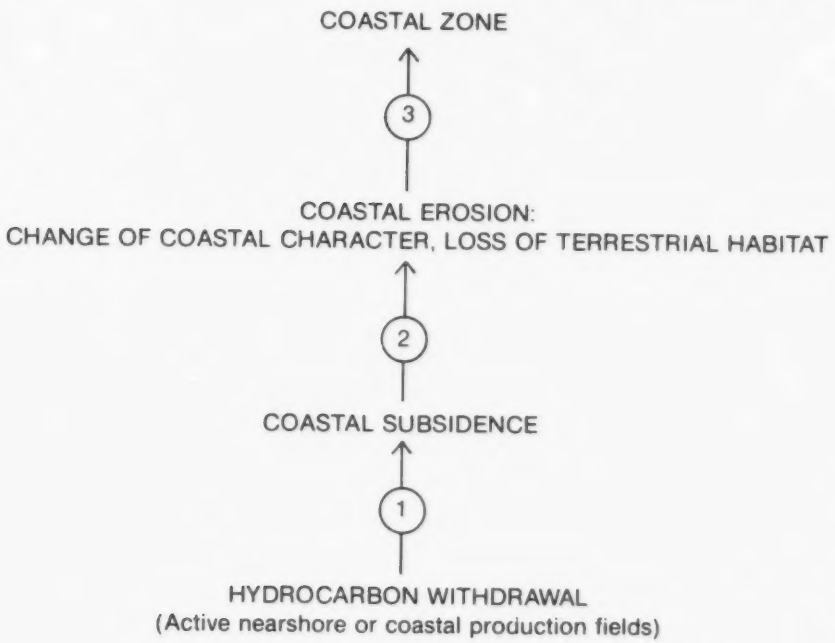
2. if altered from existing status due to development will likely result in a regulatory reponse to mitigate impacts.

It is important to note that although consideration of the COASTAL ZONE was previously omitted from consideration during the BEMP process, and that the COASTAL ZONE is specifically excluded from the MEMP process, DIAND has spent over $300,000 during the 1984/85 F.Y. on coastal monitoring programs and EPS has an ongoing monitoring program of pollutants in the coastal zone.

Specific impact hypotheses are identified below; one focuses on a process that is more regional in scope, the other focuses on site specific problems, which are similar in scope to causeway monitoring hypothesis or nearshore discharge hypotheses. The former hypothesis is particularly important in light of changes in the drilling scenario.

HYPOTHESIS 1A

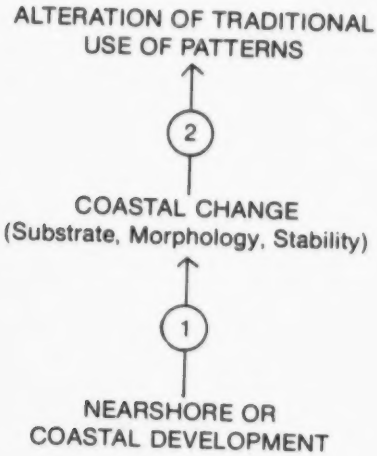
Hydrocarbon withdrawal in coastal and nearshore areas will result in coastal subsidence, and in turn result in coastal erosion and loss of terrestrial habitats.



1. There is abundant evidence in low-lying areas of the Gulf of Mexico that hydrocarbon withdrawal results in subsidence.
2. In low lying areas, minimal subsidence will result in coastal erosion, changes in coastal and nearshore morphology and loss of terrestrial habitats. In the Bay Marchaud oil field of southern Louisiana (located within a few kilometres of the coast) there are documented coastal retreat rates in excess of 30 m/yr.
3. Similar impacts have resulted in regulatory agencies imposing mitigation measures (injection of salt water into production wells to minimize subsidence).

HYPOTHESIS 1B

Establishment of shore facilities (support base, harbours, pipeline landfalls, breakwaters, wharfs or causeways) will cause changes in the coastal zone, including substrate type, coastal stability, coastal morphology or habitats. These changes in turn will alter traditional use patterns of the native people.



1. There is abundant evidence that coastal development will result in direct coastal change; the scale of this change varies widely depending on the type of development.
2. Should a specific development result in a comparatively small change, this link could be considered "weak", and the hypothesis not valid.

Should a larger scale change be apparent or should some particularly significant resource be affected (e.g., closing of an inlet which would cause a lagoon to change from marine to freshwater), then the link might be considered "strong", and the hypothesis valid.

The hypothesis assumes additional prominence if the native people are considered a VEC (i.e., shore development changes traditional use patterns).

BEMP MANAGEMENT COMMITTEE RESPONSE

Several members of the BEMP Management Committee have reviewed Dr. Harper's proposal to add the coastal zone to the list of Valued Ecosystem Components. It is the view of this committee that the coastal zone *per se* is not a VEC, although it is recognized that both the coastal zone and coastal processes are important to several existing VECs. The following rationale is provided for rejection of this proposal:

1. Contrary to the statement of Dr. Harper, the coastal zone was not posed as a VEC during the relatively comprehensive discussions of a list of candidate VECs in the first BEMP workshop (May 1983), and although it has been suggested as a possible VEC on several occasions during discussions outside plenary, a review of the arguments for and against its inclusion as a VEC has not been completed within any of the past BEMP workshops. Dr. Harper implies in his memo that justification is *again* being provided for the coastal zone as a VEC. We expect that he is actually referring to "sensitive areas" (e.g., unique habitats, IBP sites, pingos) which were posed as a candidate VEC in the first workshop and subsequently rejected before the second workshop. The coastal zone was not on either of the lists of potential or final VECs described in the Interim Report (August 1983) after the first workshop (Table 1-2, p. 13; Table 1-3, p. 14).

2. Development-induced changes in the coastal zone that do not affect one of the existing VECs are not likely to merit specific research or monitoring, in the context of the BEMP process and its overall objectives.

3. Hypothesis 1A proposed by Dr. Harper which states that "hydrocarbon withdrawal in coastal and nearshore areas will result in coastal subsidence, and in turn result in coastal erosion and loss of terrestrial habitats" is plausible and, in fact, is being addressed by one of the working groups in the Mackenzie Environmental Monitoring Program (MEMP). The important point that should be emphasized here is that "habitats of a VEC" rather than the coastal zone *per se* (as suggested by Dr. Harper's flowchart) are the focus of the MEMP review. It is also noteworthy that the coastal zone was rejected as a VEC in plenary sessions during the first MEMP workshop, but it is recognized by both BEMP and MEMP management groups and coordinators that the coastal zone is important as habitat for some VECs. In other words, changes in the coastal zone and coastal sediment transport/erosion processes that can be "linked" to existing VECs through present or new impact hypotheses are within the scope of both projects.

In summary the BEMP Management Committee believes that the coastal zone, like water and sediment quality, constitutes part of the habitat of some existing VECs addressed in this project, but is not in itself a VEC. The importance of coastal processes as a linkage in existing BEMP hypotheses is evident in the two hypotheses adddressing the possible effects of nearshore structures such as causeways on anadromous fish populations. Similarly, coastal processes were included as an important link in the new hypothesis examined during this last workshop regarding potential effects of oil-contaminated cuttings disposal in nearshore waters. It is expected that specific research or monitoring needs related to links involving coastal processes will continue to be important to address uncertainties and test cause-effect relationships that form the present basis of the BEMP process.

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